EXPLORING TEACHERS' PROCESS OF CHANGE IN INCORPORATING
PROBLEM SOLVING INTO THE MATHEMATICS CLASSROOM

by

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Exploring Teachers' Process of Change in Incorporating Problem Solving into the Mathematics Classroom

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

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DEDICATION

This dissertation is dedicated to my friends and family who supported me throughout this process. It is especially dedicated to my boyfriend, Michael, for his never-ending encouragement and ability to relieve my stress through his humorous antics. It is also dedicated to my mother, Jannine; my father, Bruce; and my sister, Breanne, who have supported me in everything that I have done throughout my life. An additional dedication goes to my beautiful niece, Olivia, who has made my life brighter every day since she was born. Finally, it is dedicated to my late grandmother, Frances, who always wanted to tell her friends in Ft. Lauderdale that her granddaughter was a doctor. I wish that you could be here to celebrate with me.

ACKNOWLEDGEMENTS

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ABSTRACT

EXPLORING TEACHERS' PROCESS OF CHANGE IN INCORPORATING
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This study explores how a problem-solving based professional learning community

(PLC) affects the beliefs, knowledge, and instructional practices of two sixth-grade

mathematics teachers. An interview and two observations were conducted prior to

beginning the year-long PLC in order to gather information about the participants'

beliefs, knowledge, and instructional practices. Five PLC meetings were held throughout

the year focused on implementing problem-solving activities into the classroom as a

means to create a mathematics learning environment more aligned with the *Standards*

(NCTM, 2000). Three observations of each participant were made while they

incorporated a problem-solving activity into their classroom. Finally, a post interview

and observation were conducted at the end of the year to again gather information on the

participants' beliefs, knowledge, and instructional practices. Results indicate that the

year-long problem-solving based PLC was effective in moving the participants' beliefs,

knowledge, and instructional practices towards a more reform-based vision of school

mathematics. The similarities and differences between the changes that both participants

went through as well as factors that may have influenced them are also discussed.

CHAPTER 1: INTRODUCTION

Currently the teaching and learning of mathematics is going through tremendous changes (White-Fredette, 2009). The National Council of Teachers of Mathematics' (NCTM) Principles and Standards for School Mathematics calls for reforms to both curriculum and classroom instruction (NCTM, 2000). NCTM's vision of school mathematics in the 21st century includes constructivist learning, student-centered classrooms, worthwhile tasks, and reflective teaching. Not only does NCTM call for changes in how mathematics is taught, but also for changes in who engages in higher level mathematics courses. NCTM's Equity Principle calls for higher expectations, challenging curricula, and high-quality instructional practices for all students.

Additionally, recent publications from the National Research Council (NRC, 2001, 2005) have in many ways, redefined the teaching and learning of mathematics. These documents call for a more problem-solving, sense-making instructional mode, which moves away from the teaching of isolated skills and procedures. This changing vision of school mathematics (student-centered pedagogy, constructivist learning, focus on problem-solving, and success for all) cannot come about without radical change in instructional practices and hence radical change in teachers' beliefs and knowledge of mathematics teaching and learning. So, how do we go about creating this change?

One direct approach to bringing about this change in teaching and learning mathematics has been the creation and incorporation of standards-based curricula (curriculum in which the content of instruction is determined and designed around national and state standards). However, just because the curriculum is said to be standards-based does not necessarily mean it actually embodies the mathematical approaches and pedagogical principles of the NCTM *Standards* (NCTM, 1989, 2000). According to some researchers (Fan & Zhu, 2007; Griffin & Jitendra, 2009; Nie, Cai, & Moyer, 2009; Pimta, Tayruakham, & Nuangchalerm, 2009) not all of the so-called standards-based/reform curricula adequately addressed the *Standards*. For example, while many curricula had sections titled "problem solving," they failed to provide opportunities for reasoning and making connections (Jitendra, DiPipi, & Perron-Jones, 2002). In sum, simply altering the textbooks will not bring about the radical change in mathematics teaching and learning that is necessary to reshape the vision of mathematics defined by the NCTM (1989, 2000) and NRC (2001, 2005). Many scholars (Charalambous & Philippou, 2010; Drake & Sherin, 2006; Hamre et al., 2012; McMullen, et al., 2005; Spear-Swerling & Brucker, 2004; Stipek & Byler, 1997) argue that teachers are the most influential agents of change.

Recently, scholars and reformers have proposed collaborative teacher communities as a means of improving teaching and learning (Levine, 2011). For the past ten years there has been a huge interest in professional learning communities (PLCs) and a striking number of texts written about them (Levine, 2011). A PLC exists when educators create an environment that fosters mutual cooperation, emotional support, and

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personal growth while all members engage in ongoing study and constant practice that work towards continuous improvement (Dufour & Eaker, 1998). In essence, "teachers work collaboratively to reflect on practice, examine evidence about the relationship between practice and student outcomes, and make changes that improve teaching and learning for the particular students in their classes" (McLaughlin & Talbert, 2006, p. 4).

A number of education researchers (Cibulka & Nakayama, 2002; Fullan 2002; Schmoker, 2004) have described learning communities in the context of school reform more broadly. Others focus on specific challenges associated with the creation and implementation of PLCs (Joyce, 2004; Levine, Laufgraben & Shapiro, 2004) and PLCs as vehicles for teacher learning and improved professional development (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Darling-Hammond & McLaughlin, 1995). More recently, literature reviews have begun to look at the impacts of PLCs on teacher learning and on student achievement (Carroll, Fulton, & Doerr, 2010; Vescio, Ross, & Adams, 2008). As a whole, the studies mentioned above look at work of PLCs both in the US and overseas, but on a very broad level. There have been a few studies conducted looking specifically at PLCs used to affect teaching and learning in mathematics.

In 2010, the National Commission on Teaching and America's Future (NCTAF) published a comprehensive knowledge synthesis of PLCs and their impact on science, technology, engineering, and mathematics (STEM). The NCTAF looked at approximately 109 resources ranging from empirical research published in peer-reviewed and non peer-reviewed journals to published descriptions of models of STEM teachers in

PLCs. The NCTAF found a small number of studies showing positive effects on

mathematics students' learning and achievement. They found that "this small set of

studies gives some proof that teacher participation in a mathematics PLC can lead to an

enhancement in what their students learn" (NCTAF, 2010, p. 8).   While these studies

showed that PLCs can have a positive effect on the students' learning of mathematics, no

studies focused specifically on how PLCs affect teachers' knowledge and beliefs about

mathematics teaching and learning, including whether or not there was any

transformation in their beliefs and knowledge towards a more problem-solving based

instructional model.

Background of the Problem

Assessing mathematics achievement in the United States has been a priority since

the 1960s. One of the objectives of the National Center for Educational Statistics

(NCES) is to provide a comprehensive picture of how students in the US perform in key

subject areas. Currently, nationally representative data on student achievement come

primarily from two sources: (a) the National Assessment of Educational Progress

(NAEP), also known as the "Nation's Report Card" and (b) U.S. participation in

international assessments, such as the Trends in International Mathematics and Science

Study (TIMSS) and the Program for International Student Assessment (PISA).

The Nation's Report Card provides information on student performance at the

national and state levels. The most recent findings about our nation's progress in

mathematics were published in 2011. The NAEP mathematics assessment measures

fourth- and eighth-graders' knowledge and skills in mathematics over five mathematical

content areas (number properties and operations, measurement, geometry, data analysis, statistics, and probability, and algebra) through questions which vary over three complexity levels based on cognitive demands (low, moderate, and high complexity). The results are reported as an average scale score ranging from 0-500 and as percentages of students performing at three achievement levels: basic, proficient, and advanced.

Overall, both fourth- and eighth-graders on average improved by one point from 2009 to 2011 (fourth-grade average score was 241 and eighth-grade was 284) (National Center for Educational Statistics [NCES], 2011). In fourth grade, 42% of the students performed at a basic level, 33% at proficient, and 7% at advanced (NCES, 2011). In eighth grade, 38% of the students performed at a basic level, 27% at proficient, and 8% at advanced (NCES, 2011). These percentages changed very minimally with a 1% improvement at the proficient and advanced levels for fourth grade and a 1% improvement at the proficient level for eighth grade. Although these improvements are very small, the most alarming result was the small percentage of students that performed at the advanced level in both grades. This means that 93% of the nation's fourth graders cannot apply integrated procedural knowledge and conceptual understanding to complex and non-routine real-world problem solving in the five content areas and 92% of eighth graders cannot reach beyond the recognition, identification, and application of mathematical rules in order to generalize and synthesize concepts and principles in the five content areas. In other words, few of our nations' students have the ability to problem solve and complete higher order thinking tasks.

Similar to NAEP but on an international scale is the TIMSS report. TIMSS

assessed fourth- and eighth-grade students in the same five mathematical content areas as

the NAEP but through a different cognitive dimension using the categories *knowing*,

applying, and *reasoning* as opposed to *low*, *moderate*, and *high* complexity levels. The

most recent TIMSS report was completed in 2007 and yielded the following results. The

average mathematics scores for both U.S. fourth and eighth graders were higher than the

TIMSS scale average (Gonzales, et al., 2008). At grade four, the average U.S.

mathematics score was higher than those in 23 of the 35 countries (Gonzales et al., 2008).

At grade eight, the average U.S. mathematics score was higher than those in 37 of the 47

other countries (Gonzales et al., 2008). In terms of the three cognitive domains, both U.S.

fourth graders and eighth graders performed relatively better in the *knowing* domain than

in the *applying* and *reasoning* domains than other countries (Gonzales et al., 2008).

Overall the results indicate that the fourth and eighth graders in the US are performing on

average better than students at the same grade levels in many countries, but they lack the

ability to apply and reason through their mathematical knowledge.

Lastly, PISA is an international mathematical literacy assessment of 15-year-olds

measuring how well students apply their knowledge and skills learned in and out of

school in mathematics to problems within a real-life context (Hopstock & Pelczar, 2011).

The literacy concept emphasizes the mastery of mathematical processes, understanding of

mathematical concepts, and application of knowledge in various mathematical situations

(NCES, 2007). The PISA mathematics framework includes content and cognitive

dimensions as well as a third dimension that describes the contexts in which mathematics

is applied. For its content dimension, PISA uses overarching ideas rather than curricular-based domains as in NAEP and TIMSS. PISA's cognitive dimension describes important mathematical competencies in three clusters: reproduction, connections, and reflection. Lastly, the context dimension describes situations in which students should be able to use and do mathematics, such as in society.

In all, 60 countries and 5 other educational systems participated in PISA 2009. U.S. fifteen year-olds had an average score that was lower than the average PISA score. Twenty-three countries had higher average scores than the US, 29 had lower average scores, and 12 had average scores not measurably different from the U.S. average score (Fleischman, Hopstock, Pelczar, & Shelley, 2010). In mathematics literacy, only 27% of U.S. students performed at or above proficiency level 4 (proficiency levels ranged from 1 to 6) (Fleischman et al., 2010). Level 4 is where students can complete higher order tasks. In sum, U.S. 15-year-olds performed below the average score, about half of the countries that participated scored the same or better, and only a quarter of the U.S. 15-year-olds were capable of performing higher level thinking tasks such as problem solving, mathematical reasoning, and application of concepts to real-life situations.

The overall performance of the U.S. students across all three assessments (TIMSS 2007, PISA 2009, and NAEP 2011) improved very minimally from prior assessment years. In addition, all three of these reports indicate that on average students in the US lack the ability to perform higher order thinking tasks in mathematics. Further, compared to other countries the U.S. students are below the average score with many countries performing better. These findings are not a revelation; past reports have indicated the

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same findings and provide further evidence for the need for more problem-solving/higher order thinking activities to be incorporated into mathematics instruction.

For more than fifteen years, there have been many efforts to implement mathematics education reform (Drake & Sherin, 2006). This reform movement in mathematics education calls for students to engage in problem solving. Specifically, the Problem Solving process standard states that students require frequent opportunities to formulate, grapple with, and solve complex problems. Also, students need time to reflect on their thinking during the problem-solving process so that they can apply and adapt the strategies they develop to other problems (NCTM, 1989, 2000). As a result, teachers must change their instructional practices to incorporate problem-solving practices into their classroom, which often necessitates adding to their pedagogical knowledge through teacher learning experiences.

Research shows that to effect change, curricula need not only support student learning, but also directly address teachers' learning and teaching needs (Drake & Sherin, 2006). Simply providing a teacher with the materials (reform curricula) does not ensure that the teacher will change instructional practices and implement a problem-solving approach that is effective. Teachers' knowledge and beliefs must be considered when trying to bring about change (Ambrose, 2004; Drake & Sherin, 2006; Ford 1994; Pajares, 1992; Vacc & Bright, 1999). Therefore, for teachers to meet the demands of new mathematics reforms (incorporating a problem-solving approach to teaching mathematics), teacher educators and researchers must consider how to assist teachers in this process of change.

Research conducted in the area of moving teachers towards a more reform/problem-solving way of teaching mathematics has yielded four important findings. First, teachers need to understand how children's mathematical learning develops, how children think about mathematics, and what strategies they use in problem solving (Ambrose, 2001, 2004; Benken & Wilson, 1996; Bright & Vacc, 1994; Chauvot & Turner, 1995; Crespo, 2003; Kazemi & Franke, 2004; Lubinski, 1993; McGatha & Sheffield, 2006; Steinberg, Carpenter, & Fennema, 1994; Steinberg, Empson, & Carpenter, 2004; Timmerman, 2004; Vacc & Bright, 1999; Vacc, Bright, & Bowman, 1998). Second, teachers need to be given opportunities to share and discuss their reflections and experiences while implementing new instructional practices (Artzt, 1999; Chapman, 1999; Crespo, 2003, McGatha & Sheffield, 2006). Third, teachers need to continue to assess students' mathematical thinking and knowledge throughout the entire year by having small group and whole group discussions where students talk over and question one another about various strategies and solutions (Bass & Glaser, 2004; Lubinski, 1993). Finally, when possible, teachers should be involved in the development or design of new reform curricula or programs (Drake & Sherin, 2006; Hojnacki & Grover, 1992. I included all four findings in the design of the professional learning community for this study.

The Purpose of This Study

Although, as noted above, there has been research on teacher change towards a more reform/problem-solving way of teaching mathematics, little research has combined all four findings. In addition, the majority of these studies were conducted with

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preservice teachers rather than with experienced teachers. The study presented here was designed to address that lacuna by exploring the issue of teacher change when experienced teachers implement problem solving in their classroom. These teachers worked together to create problem-solving activities that elicited students' thinking, reflected on and discussed with one another their discoveries about the students' problem-solving strategies, and then shared their experiences during implementation. This study aims to answer the following research questions:

1. How do two grade six teachers respond to a problem-solving based professional learning community (PLC)?

   a. Do these teachers' beliefs and knowledge change, if so, in what ways?

   b. Do these teachers' instructional practices change, if so, in what ways?

2. What influences these teachers' decision making throughout the year?

3. What are the decision-making practices of a teacher leader?

Definitions

There are several definitions found in the broader literature for these four key terms used in this study: *belief*, *knowledge*, *problem-solving*, and *professional learning communities (*PLC). To ensure readers and author have a shared meaning for these terms in this study, I offer the following definitions.

Knowledge Versus Beliefs

I define knowledge and beliefs in one section because not only is it often difficult to differentiate between the two, but they also frequently influence one another. For years scholars have struggled to distinguish knowledge from belief, yielding varying

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definitions (Pajares, 1992). According to Pajares (1992) the variations in the definitions may be due to the different agendas of researchers. For this study, however, I needed clear definitions; to create them I used the various definitions of previous scholars as both terms apply to my study. Knowledge is the cognitive outcome of thought, which is systematically organized and requires a general or group consensus regarding its validity and appropriateness (Ernst, 1989b; Nespor, 1987). Knowledge is based on objective fact (Pajares, 1992). There is knowledge of *what* (e.g., knowing classroom management strategies), knowledge of *how* (e.g., understanding how to execute each strategy), and knowledge of *when* (e.g., knowing when or under what conditions a particular classroom management strategy is appropriate) (Greeno, 1978; Paris, Lipson, & Wixson, 1983). In summary, I defined knowledge for this study as objective facts that a teacher acquires through education and experiences in order to understand what concepts to teach, and how and when to teach them.

Belief, on the other hand, is the affective outcome of thought, which is held to be true by that individual and guides behavior (Ernst, 1989b; Harvey, 1986). Belief is based on evaluation and judgment (Pajares, 1992). A belief is a person's judgment of the truth or falsity of an idea, which is inferred from a collective understanding of what human beings say, intend, and do (Pajares, 1992). Beliefs are peoples' manipulation of knowledge for a particular purpose or under a necessary circumstance (Abelson, 1979). In summary, I defined beliefs for this study as subjective thoughts based on an individual's interpretation and internalization of information learned.

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Problem Solving

Many often contradictory definitions of problem solving have been proposed through the years, ranging from any task to be undertaken, to activities requiring application of particular procedures, to dealing with "word problems," and so on (Monaghan, Pool, Roper, & Threlfall, 2009). Polya's (1945) definition, which focuses on the cognitive processes involved when dealing with situations that present questions, influenced many subsequent definitions, including those of NCTM and PISA. NCTM (2000) defines problem solving as "engaging in a task for which the solution is not known" (p.52). PISA (2003) defines problem solving "as an individual's capacity to confront and resolve. . .situations where the solution path is not immediately obvious" (p. 156). Other researchers' definitions are centered around the thought processes involved in problem solving. Burton (1984) suggested there are three phases to problem solving: entry (making sense of the situation), attack (applying a strategy), and review/extension (testing the solution and generalizing). Orton (1992) explained that both convergent thinking (reasoning that narrows the focus) and divergent thinking (a more creative process of widening the focus, using transformation of meanings and interpretations) are needed in problem solving.

Based on these definitions and explanations, for this study I defined problem solving as students trying to find an answer to a mathematical question without knowing any particular method for getting to the solution. One student may construct one strategy/method to arrive at an answer that differs from that of another student.

PLC

Scholars and reformers have proposed collaborative teacher communities in schools as a way for leaders to improve teaching and learning (Levine, 2011). The terminology for such a practice varies amongst these scholars and reformers: *teacher professional community, professional learning communities*, *inquiry communities*, *instructional communities of practice*, and so on (Levine, 2010). The school where I conducted this study uses the term *professional learning communities* (PLC) to represent its teacher collaborative communities. Therefore I use PLC in this study for the year-long staff development program that I lead. For this study, I defined PLC as a group of teachers working collaboratively during an entire school year towards continuous improvement in a particular area of teaching and learning (DuFour & Eaker, 1998). In this study the focus of improvement was on incorporating problem solving into the mathematics classroom. I further defined PLC as a staff development process where teachers reflect on practice, examine and discuss evidence observed in their classrooms about the relationship between practice and student outcomes, and create and implement new teaching practices that will improve teaching and learning (McLaughlin & Talbert, 2006).

CHAPTER 2: LITERATURE REVIEW

Since this study explores problem solving and teacher change as they relate to teachers' beliefs, knowledge, and instructional practices, it is important to understand what is already known about these topics. Specifically, this review will address the following: the nature of problem solving, why problem solving is important, factors that positively and negatively influence teacher change, and professional development that can be used to foster change towards implementing problem solving in the mathematics classroom.

What is Problem Solving?

Definition According to the National Council of Teachers of Mathematics (NCTM)

According to NCTM (2000) "problem solving means engaging in a task for which the solution method is not known in advance" (p. 52). This can encompass many things in mathematics. However, NCTM goes further in defining problem solving by providing four major features that mathematics instruction should include: (a) using problem solving to assist students in building new mathematics knowledge, (b) providing problems to solve that are found in both mathematics and in other contexts such as the students' own worlds, (c) allowing and teaching students to apply and adapt a variety of appropriate strategies to solve problems, and (d) offering students chances to monitor and reflect on the process of mathematical problem solving (NCTM, 2000). Finally, problem

solving should be interwoven throughout the mathematics curriculum and not taught as a

separate topic (NCTM, 2000).

Definition According to the Program of International Student Assessment (PISA)

PISA (2003) acknowledged that "problem solving is a central educational

objective within every country's school program" (p. 154), but that there is no universally

accepted definition of problem solving. As a result, PISA proposed this definition:

> Problem solving is an individual's capacity to use cognitive processes to confront
>
> and resolve real, cross-disciplinary situations where the solution path is not
>
> immediately obvious and where the literacy domains or curricular areas that
>
> might be applicable are not within a single domain of mathematics, science, or
>
> reading. (PISA, 2003, p. 156)

PISA further explained that this definition of problem solving emphasizes solving real-

life problems through "understanding the information given, identifying the critical

features and their relationships, constructing or applying an external representation,

solving the problem, and evaluating, justifying, and communicating solutions" (PISA,

2003, p. 154).

Teacher Beliefs about Problem Solving

NCTM and PISA have both defined problem solving, but perhaps even more

critical to this study are teachers' beliefs about problem solving, because they are the

ones who ultimately make the decisions about implementing problem solving into their

classrooms (Ambrose, 2004; Drake & Sherin, 2006; Ford 1994; Pajares, 1992; Vacc &

Bright, 1999).

Traditional beliefs. Despite NCTM's (2000) proposed definition of how

problem solving should be incorporated into the classroom, researchers have found that

many teachers still hold traditional views of problem solving (Bright & Vacc, 1994;

Capraro, 2001; Chapman, 1999; Chauvot & Turner, 1995; Crespo, 2003; Ford, 1994;

Gravemeijer, 1997; Millard, Oaks, & Sanders, 2002). Capraro (2001) surveyed 123

fourth- and fifth-grade teachers using a Likert-type instrument entitled, *Mathematics

Beliefs Scales* (Fennema, Carpenter, & Loef, 1990) to determine those teachers with

high- and low-constructivist beliefs. Capraro (2001) discovered that many teachers had

low-constructivist beliefs, meaning they think of mathematics as simply computation and

do not feel that students are ready to engage in problem-solving activities until they have

mastered the facts. This narrow conception of mathematics deprives students of

problem-solving experiences that could help them gain deeper mathematical

understandings of concepts (Capraro, 2001). Instead, Capraro (2001) suggests that rather

than seeing problem solving as a topic to teach when students are ready, teachers should

visualize it as a process arching over all other mathematical concepts and skills,

providing a sort of protective umbrella where all the topics can be learned—a more

constructivist way of thinking.

In addition, Bright and Vacc (1994), Ford (1994), and Millard et al. (2002) found

that many teachers believed simply posing a word problem to the students and having

them apply a learned strategy qualified as problem solving. With this approach, teachers

were delivering information and telling the students what to do; teachers taught various

problem-solving strategies (i.e., working backwards, drawing a picture, looking for a

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pattern, guessing and checking, etc.) one at a time and gave the students word problems where they simply had to apply that strategy that had been taught (Bright & Vacc, 1994). In essence, this is exactly like the traditional drill and practice method of teaching mathematics and problem solving is primarily used as an application of computational skills (Ford, 1994). Further, these teachers focused primarily on correct answers rather than the mathematical thinking process students used while solving the problems (Bright & Vacc, 1994; Ford, 1994; Millard et al., 2002).

Gravemeijer (1997) found that teachers equated problem solving with solving word problems. However, he did not label and discuss this as an incorrect belief, but rather noted what was wrong with the word problems students were given to solve. For example, according to Gravemeijer (1997) word problems often consist of single-step solutions where students are to find the solutions quickly, no reflection or discussion is needed, and no connection is made with everyday life. Gravemeijer (1997) suggests that word problems should be modified in the following ways so that students are required to use higher order thinking skills to solve them: (a) include superfluous information or omit information; (b) require complex, multi-step processes in order to arrive at a solution; and (c) incorporate realistic situations that also consider realistic answers.

Like Gravemeijer (1997), Crespo (2003) also supported the notion of problem solving via posing word problems. She found that most frequently students were given single step, computational problems. This discovery led her to explore whether teachers' problem posing strategies could evolve.

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The participants in Crespo's (2003) study were 34 elementary pre-service teachers enrolled in an experimental mathematics teacher education course, which ran for 11 weeks and included one seminar and one field experience class per week. In each seminar, the teachers were engaged in doing mathematics (e.g., solving problems and discussing solution methods) and pedagogical explorations (e.g., analyzing the instructional value of problems, anticipating students' work, re-scaling problems for different grade levels). The participants could choose from two field experiences: (a) conducting small group teaching sessions with students in grades six and seven (14 participants), or (b) exchanging weekly mathematics letters with one or two fourth graders (20 participants). The three main sources of data were: (a) the mathematics letter exchanges between participants and students, (b) the teachers' weekly math journals, and (c) the final case report submitted by each participant at the end of the course.

The results showed a significant change in the participants' problem-posing practices. Instead of posing traditional single-step problems, the participants began posing problems that had multiple approaches and solutions, were open-ended and exploratory, and were cognitively more complex (Crespo, 2003). As a result of using these more complex problems, teachers' problem-posing style evolved: they no longer led the students toward a solution, were not so concerned with the correct answer, and were less focused on avoiding students' errors. Crespo (2003) also found that the problems and the teachers' problem-posing styles reflected a classroom that was aligned with NCTM (2000) standards. This suggests a question about the difference between problem posing and problem solving.

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Additionally, Chapman (1999) and Chauvot and Turner (1995) also found that the teachers in their studies had the traditional beliefs about problem solving discussed above. However, these teachers were aware of NCTM's new reform ideas, particularly the standards involving problem solving; nonetheless, their instructional practices reflected traditional views (posing a word problem, having the students solve the word problem, and focusing on the correct answer rather than strategy and mathematical thinking) (Chapman, 1999; Chauvot & Turner, 1995). In addition, these teachers characterized themselves as not having strong mathematics backgrounds and harboring negative attitudes towards mathematics (Chapman, 1999). These self-characterizations raise questions about the relationships among teachers' beliefs, mathematics background, and instructional practices. Teachers may believe in current reform standards, but lacking a strong background in mathematics and experience with such reform practices, they do not feel capable of implementing reform practices and therefore revert to the traditional practices and beliefs they are comfortable with.

Lastly, Ernst (1989a, 1991) defined three categories to describe teachers' beliefs about the nature of mathematics: problem-solving, platonist, and instrumentalist. According to this categorization, teachers with the problem-solving view think of themselves as facilitators encouraging their students to pose and solve problems; they value students' construction of their own knowledge. A teacher with a platonist view is an explainer, but still values conceptual understanding. Finally, an instrumentalist teacher emphasizes mastery of skills, rules, and procedures. The student's role is to master what the teacher explains. Ernst's (1989a) problem-solving view aligns with

NCTM's description of problem solving, but in conducting studies using these three views to measure teacher beliefs, Ernst (1989a) and Benken and Wilson (1996) discovered a disparity between espoused beliefs and what the teacher actually does in the classroom. Teachers' beliefs about problem solving may not necessarily influence how they implement problem solving in the classroom.

In summary, the traditional belief holds that problem solving is generally incorporated into the classroom as a separate skill. According to this belief students learn problem-solving strategies and then apply them to specific word problems. Essentially, this procedure is exactly like the computation procedure, with the one exception that word problems are used. However, from the body of research examined above, three questions arise: (a) What is the difference between problem posing (providing students with a multi-step word problem to solve) and problem solving and is there a way to bring problem posing into alignment with NCTM standards? (b) How do teachers' experiences influence their beliefs and, hence, their instructional practices? and (c) Why do teachers' espoused beliefs and actual instructional practices sometimes differ?

Reform beliefs. Although some teachers still hold traditional beliefs about problem solving, researchers have found that others have problem-solving beliefs that align with NCTM's definition (e.g., Collier, Guenther, & Veerman, 2002; Drake & Sherin (2006); Fennema et al., 1996; Fernandez (1997); Vacc & Bright, 1999; Vacc et al. (1998). Fennema et al., (1996), Vacc and Bright (1999), and Vacc et al. (1998) have conducted extensive research with Cognitively Guided Instruction (CGI). CGI is an approach to teaching mathematics that uses research-based knowledge about children's

mathematical learning to make decisions about teaching. Students in CGI classrooms spend most of their time solving various problems by creating their own solutions, sharing their solution strategies, and asking questions of one another and the teacher (Vacc & Bright, 1999). By incorporating such an approach into the classroom, teachers demonstrate a belief in problem solving as the essential means for learning mathematics, a reflection of reform standards (Vacc & Bright, 1999; Vacc et al. 1998).

Similarly, Collier et al. (2002) found that some teachers believed in incorporating problem solving as a means for students to learn new concepts by applying what they already know. This approach was referred to as problem-based learning, where the teacher poses an open-ended problem to the class and the students work in groups and use prior knowledge and multiple strategies to find a solution (Collier et al., 2002). The students then discuss their solutions with the entire class.

Collier and her colleagues (2002) chose two special education classrooms (one kindergarten and one eighth-grade class) based on data indicating these children had a deficit in critical thinking and problem-solving skills. During an 11-week intervention, teachers used problem-based learning as an instructional strategy to challenge the students' critical thinking and problem-solving skills. Pretest and posttest data were collected on the skills of sorting, recalling, describing, problem solving, predicting, and estimating. The post-intervention data revealed definite improvements in students' critical thinking and problem-solving skills in both classes. This progress indicated that a problem-based learning environment can yield positive results in problem-solving skills development.

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An even more promising result in Collier's (2002) study was related to a type of problem-based learning where the teacher serves as a facilitator and the students are responsible for constructing knowledge and learning about mathematics. This result showed teachers that students, when given the opportunity to take charge of their learning, can be successful with less teacher guidance. Teachers that use problem-based learning in their classrooms often believe that problem solving is essential to learning (Collier et al., 2002).

In a study similar to Collier's (. 2002), Fernandez (1997) investigated the instructional practices of nine secondary teachers who believed in mathematics instruction based on the NCTM principles and standards (2000). All of these teachers believed in allowing their students to explore and experiment with mathematical concepts via problem solving and discussion. In examining the actions of these nine teachers, Fernandez (1997) found they used four strategies during instruction (beyond simply incorporating problem solving and discussion) that especially promoted a reform-based classroom: (a) generating counter examples as a way to challenge their students and enable them to examine their perspectives, (b) following through on a student's idea to clarify a misunderstanding, (c) asking students to think of a simpler or related problem to assist in solving a problem, and (d) understanding and incorporating a student's method of understanding mathematical concepts. These teachers did not use a particular curriculum or instructional approach; rather, their instructional practices were a result of their beliefs and knowledge about teaching and learning mathematics.

On the other hand, Drake and Sherin (2006) conducted a study following 20 elementary school teachers for three years. All implemented a reform-based curriculum, *Children's Math Worlds* (*CMW*). *CMW* is a curriculum aligned with many ideals of the NCTM *Principles and Standards* (2000) and seeks to promote student understanding of mathematics through the use of meaningful verbal, situational, and visual representations as well as through classroom discourse around problem solving and students' multiple solution methods (Drake & Sherin, 2006). By using this curriculum the teachers provided mathematical instruction laden with problem-solving experiences.

Data sources for Drake's study (Drake & Sherin, 2006) included observations of the participants teaching mathematics lessons throughout the school year, interviews, and mathematics story interviews written by the participants. The participants also went to professional development sessions designed around the curriculum, approximately once a month. After analyzing the data, the researchers discovered that, although the teachers' instructional practices reflected reform-based standards, their beliefs did not always match instructional practices. Curriculum implementation was more successful for those teachers whose beliefs matched the instructional practices. This finding raises a question about sequence: which came first? The teachers' beliefs or the curriculum?

In sum, some teachers' beliefs align with the principles and standards set forth by NCTM (2000). Some of these teachers incorporate reform-based teaching approaches, such as CGI or problem-based instruction. Others use reform-based curricula and still others develop a combination of practices based solely on their own beliefs and knowledge about the teaching and learning of mathematics. The task for the field of

mathematics education is to help all teachers to understand, invest in, and implement

reform-based standards that promote problem solving.

Incorporating Problem Solving Into Instruction

"Problem solving is the cornerstone of school mathematics. . .without the ability

to solve problems, the usefulness and power of mathematical ideas, knowledge, and skills

are severely limited" (NCTM, 2000, p. 182). In response to NCTM's principles and

standards for mathematics (1989, 2000), numerous studies have been conducted to

examine the effects of problem solving on students' achievement, attitudes, and

motivation in mathematics (Capraro, 2001; Carroll & Isaacs, 2003; Collier et al., 2002;

Fennema et al., 1996; Fraivillig, Murphy, & Fuson, 1999; Fuson, Carroll, & Drueck,

2000; Hickey, Moore, & Pellegrino, 2001; Householter & Schrock, 1997; Jitendra et al.,

2002; Kjos & Long, 1994; Kroesbergen, Van Luit, & Maas, 2004; Kulm, Capraro, &

Capraro, 2007; McGatha & Sheffield, 2006; Millard et al., 2002; Riordan & Noyce,

2001; Schoenfeld, 2002; Steffe & Kieren, 1994; Thomas, 2006; von Glasersfeld, 1981;

Windschitl, 2002). When the method of incorporating problem solving into instruction is

analyzed, these studies fall into three categories: (a) reform-based instructional

approaches, (b) constructivist models of teaching mathematics, and (c) approaches

focused on solving word problems.

Using a Reform-Based Instructional Approach, Program, or Curriculum

The first set of studies all implemented some type of problem-solving approach,

which is a large component of reform-based instruction. Capraro (2001), Fennema et al.,

(1996), and Householter and Schrock (1997) each examined classrooms where the

teachers were implementing CGI (where teachers focus on allowing students to explore

multiple strategies for solving mathematical problems). All three studies indicate that

when CGI instruction was used, the students showed higher academic success in all

aspects of mathematics and were more motivated to learn mathematics (Capraro, 2001;

Fennema et al., 1996; Householter & Schrock, 1997).

Next, certain curricula were found to make a difference as well. Several

researchers (Carroll & Isaacs, 2003; Fraivillig et al., 1999; Fuson et al., 2000; Riordan &

Noyce, 2001; Schoenfeld, 2002) explored the effects of implementing a reform-based

curriculum, *Everyday Mathematics* (University of Chicago School Mathematics Project,

1998). *Everyday Mathematics (EM)* was created by the University of Chicago School

Mathematics Project (UCSMP) and is a National Science Foundation (NSF) funded

curriculum which incorporates problem solving throughout the curriculum. All studies

found that students using *EM* outperformed students using traditional curriculum across

all grade levels on tests of conceptual knowledge and problem solving (Carroll & Isaacs,

2003; Fraivillig et al., 1999; Fuson et al., 2000; Riordan & Noyce, 2001; & Schoenfeld,

2002).

Similarly, Kulm et al. (2007) examined the effects of implementing another

curriculum program, *Connected Mathematics* (Lappan, Fey, Fitzgerald, Friel, & Phillips,

1998). *Connected Mathematics (CMP)* is a standards-based reform mathematics program

for middle school grades. Students work with real-life problems for each lesson, using

calculators and a variety of other materials to discover a strategy to solve the problems.

The curriculum is spiraling, meaning the mathematical ideas are revisited from unit to

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unit and grade to grade in increasingly more sophisticated ways rather than recursively. The study used a pretest-treatment-posttest design. The students' mathematics achievement scores on their fifth-grade state assessment served as the pretest data; their scores a year later on the sixth-grade state assessment were used as the posttest data. The treatment was the implementation of *CMP* during the entire sixth-grade year. Complete data were obtained from 105 sixth-grade student participants. In addition to the quantitative data, the three teacher participants were observed six times during their lessons in order to gather qualitative data about the level of implementation and fidelity to the curriculum materials.

The qualitative data analysis indicated that the three teacher participants' implementation approaches varied depending mostly on how closely the *CMP* instructional approach matched their own teaching methods (Kulm et al., 2007). Kulm et al. (2007) discovered that all three teachers regularly used *CMP,* but one of the teachers was not as familiar with the program and therefore sometimes reverted to using more traditional strategies. The quantitative results showed a significant overall improvement on the state assessment for all students from the previous year. The most significant improvement, however, was seen with the at-risk students. Overall, the results of this study had three significant findings: (a) teachers' level of implementation of a reform-based curriculum depended mostly on how it aligned with their already established teaching styles, (b) student academic performance can be improved through the use of a reform-based curriculum, and (c) at-risk students showed the greatest academic gains (Kulm, et al., 2007).

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Lastly, a few researchers have studied what effects simple programs or changes to problem-solving instruction had on students (Collier et al., 2002; Kjos & Long, 1994; Thomas, 2006). As mentioned earlier, Collier et al. (2002) discovered that by teaching through problem-based learning, students' problem-solving skills as well as critical thinking skills in mathematics increase. Thomas (2006) examined students' gains in problem solving after the THINK intervention framework was used in classrooms with pre-service teachers in first, second, and sixth grade compared to classes in each of those grade levels that did not use THINK, but were working on problem-solving activities. The THINK framework was developed for a Title 1 urban elementary school to help children learn to share their reasoning and thinking related to problem solving. The THINK interaction framework is: **T**alk about the problem with one another, **H**ow can the problem be solved? **I**dentify a strategy for solving the problem, **N**otice how your strategy helped you solve the problem, and **K**eep thinking about the problem (Thomas, 2006). Student growth was measured by asking all students to solve four word problems with explanation before implementing THINK. Then the students were asked to again solve four word problems with explanation, after implementation of THINK. The data from 112 student pretest-posttest scores showed greater overall growth in problem-solving abilities in the students using THINK versus the students without THINK. Overall, these results indicate that a problem-solving program that encourages students to think about and share their problem-solving strategies can improve overall performance (Thomas, 2006).

Kjos and Long (1994) studied a sample of 171 fifth graders in two school districts (one urban and one suburban). The fifth-grade students in both these school districts had been found to have underdeveloped critical thinking skills based on a pretest. Data such as teacher observations, tests, and student surveys were collected to determine probable cause for the underdeveloped critical thinking skills. Analysis of the probable cause data revealed that students' strategies for problem solving were inadequate, they lacked confidence in their math ability, and were unable to communicate their thinking. Reviews of curricular content and previous instructional methods revealed an overemphasis on basic skills and computation, with minimal attention to higher-order thinking and problem solving. Kjos and Long (1994) concluded that when teachers began teaching students multiple problem-solving strategies, using manipulatives, and discussing students' thinking via oral and written communication, students developed better attitudes about mathematics. Their ability to communicate their mathematical thinking increased, and they improved their ability to solve any mathematical problem.

Using a Constructivist Model of Teaching

Other researchers investigated mathematics classrooms where teachers were incorporating a constructivist model of teaching (Hickey et al., 2001; Kroesbergen et al., 2004; Steffe & Kieren, 1994; von Glasersfeld, 1981; Windschitl, 2002). By using a constructivist model of teaching, the teachers allowed the students to take an active role in their learning, exploring the many mathematical concepts via group work, discussions, and problem solving. Hickey et al. (2001) studied 19 fifth-grade classrooms from four schools that were revising their mathematics curriculum to promote constructivist

instruction. The motivational experiences and beliefs of the fifth graders were measured using surveys and their mathematics achievement was measured comparing the results of their third-grade and fifth-grade Iowa Test of Basic Skills scores. Data analysis revealed that the more constructivist the mathematics curriculum, the higher the gains both motivationally and academically for the students (Hickey et al., 2001).

Kroesbergen et al. (2004), Steffe and Kieren (1994), von Glasersfeld (1981), and Windschitl (2002) all found similar results: students exposed to constructivist learning principles were more motivated to learn and improved their conceptual learning and problem-solving skills. Kroesbergen et al. (2004) studied 265 students aged 8-11 in a group intervention design that included two experimental groups (explicit instruction and constructivist instruction) and a control group (regular curriculum instruction). In the explicit instruction group, the teacher first always told the students how and when to apply a problem-solving strategy. The students then solved the problem using that strategy. During constructivist instruction, the teacher presented a problem-solving activity and the students came up with their own way of solving it. The teacher supported the students by asking questions and promoting discussions. Finally, students in the control group received instruction based on the regular curriculum used in the school. Pre-, post-, and follow-up tests were conducted to measure problem solving and strategy use and a motivational questionnaire was administered before and after the intervention. In addition to determining the effectiveness of a constructivist model of teaching, Kroesbergen et al. (2004) also found that students with learning disabilities greatly benefited from instructional practices reflecting a constructivist view. Overall, these

researchers' findings indicate that simply teaching mathematics using a constructivist model can yield great academic and motivational gains.

Using Word Problems

The last group studies all implemented specific problem-solving instruction by teaching problem-solving strategies using word problems. McGatha and Sheffield (2006) discussed a summer program in which students entering second, third, and fourth grade were given specific mathematical problems and told to use their prior knowledge to solve them. These problems consisted of open-ended word problems requiring multiple steps to solve. The students worked in groups and spent a lot of time trying out different strategies that they came up with on their own to understand and solve each problem. After examining the effects of this summer institute, the researchers found that students increased their problem-solving skills and overall understanding of mathematical concepts as well as developed positive attitudes towards tackling more difficult mathematical problems.

Both Millard et al. (2002) and Jitendra et al. (2002) examined classrooms where teachers specifically taught various problem-solving strategies for students to learn and apply when solving mathematical word problems. Millard et al. (2002) studied second-, fourth-, and fifth-grade classes that all participated in a four-month intervention program where six specific problem-solving strategies were taught to the students. Those problem-solving strategies included: choose an operation, work backwards, draw a picture, look for a pattern, guess and check, and use data from a chart. To measure the students' improvement a pretest-posttest model was used. Jitendra et al. (2002) looked

specifically at four middle school students with learning disabilities. These students participated in an intervention which used schema-based word-problem-solving instruction.

Both researchers concluded that by systematically teaching the students problem-solving strategies, these students were able to solve word problems consisting of various mathematical concepts such as multiplication and division, money, and applied mathematics (Millard et al., 2002; Jitendra et al., 2002). Further, according to these two studies, students were able to continue using these problem-solving strategies over time and became more enthusiastic about solving word problems.

In conclusion, all of these studies that discussed the effectiveness of problem solving indicated that problem-solving practices have positive effects on students' overall mathematical understanding, attitudes towards mathematics, and higher order and problem-solving skills. Whichever practice teachers used to incorporate problem solving (implementing reform-based instructional approaches, programs, or curricula; changing instructional practices to reflect a constructivist way of teaching; or teaching problem solving via teaching specific strategies and using word problems), students' mathematical understanding improved. Clearly, as NCTM states, problem solving is the cornerstone of mathematics (NCTM, 2000).

Teacher Change

Problem solving has been proven to be paramount to mathematical teaching and learning; however, based on what is known about teachers' instructional practices, not all classrooms incorporate problem solving (Steinberg et al., 2004). Therefore, what induces

teachers to change their instructional practices? A large body of research has been

conducted on teacher change. However, for this study only that part of the research that

looks specifically at changing teacher beliefs and instructional practices about

mathematics teaching and learning as well as how professional development related to

mathematics teaching affects teacher change.

Teachers' Beliefs

Many studies have examined teacher change in general with respect to

mathematics instruction. These studies suggest that the most influential factor in teacher

change was a teacher's beliefs.   According to researchers, teachers' beliefs are largely

influenced by their experiences in learning mathematics, and teachers frequently teach

mathematics as they were taught (often a traditional approach to mathematics instruction

consisting of drill and practice) (Ambrose, 2001, 2004; Artzt, 1999; Benken & Wilson,

1996; Bright & Vacc, 1994; Chauvot & Turner, 1995; Crespo, 2003; Emenaker, 1995;

Steinberg et al., 2004; Timmerman, 2004). As a result, the teachers' "traditional" beliefs

about mathematics instruction are passed on to their students, who in turn, if they become

teachers, pass them on to their students, and so on (Emenaker, 1995). However, NCTM's

new reform standards (1989, 2000) discourage this traditional approach and call for a

mathematics classroom that encourages a more constructivist model of teaching (students

actively participating in mathematical tasks that foster understanding).

The following section focuses on research examining the various factors that

positively and negatively affect teachers' beliefs about mathematics teaching and

learning. These studies can be organized into three categories: (a) changing teachers'

pedagogical content knowledge, (b) curricular influences, and (c) teacher reflection.

Changing teachers' pedagogical knowledge. According to Ball (1990) and Ma

(1999), teachers' pedagogical content knowledge (knowledge about the teaching

practices and learning specific to a content area) is extremely important when considering

changing teachers' beliefs and, ultimately, their instructional practices. Some researchers

have examined teachers' pedagogical content knowledge in the context of teacher change

during mathematics methodology courses. Other researchers have examined how

teacher's pedagogical content knowledge can be affected through observing/studying

children's mathematical thinking. Such observation is important to this study as the

participants observed their students during problem-solving activities.

Mathematics methods classes. Several researchers have examined changes in

pre-service teacher beliefs after exposure to different mathematics methods courses and

student teaching (Benken & Wilson, 1996; Bright & Vacc, 1994; Chauvot & Turner,

1995; Crespo, 2003; Timmerman, 2004). In a case study by Benken and Wilson (1996),

a secondary pre-service teacher attended a mathematics method course that required

students to explicitly connect their views, experiences, and understandings of reform

themes. In addition, each pre-service teacher taught in a reform-oriented classroom. The

findings indicated that the pre-service teacher's beliefs, which were grounded in

traditional views of mathematics instruction, did not change as a result of attending the

mathematics method class and doing student teaching (Benken & Wilson, 1996).

However, despite this lack of change, the researchers discovered through class

observations that the pre-service teacher was indeed incorporating reform-based practices into the classroom. Benken and Wilson (1996) concluded that there was a disconnect between espoused beliefs and actual teaching practices and speculated about whether teachers must hold beliefs that favor reform-based instruction to teach in innovative ways.

Bright and Vacc (1994) examined and compared pre-service teachers' beliefs and practices in two teacher cohorts, one CGI and the other non-CGI. They discovered that both cohorts showed changes in their beliefs as a result of methods courses, but that the CGI cohort continued to change dramatically as a result of their student teaching experiences. However, another important discovery was that many of the teachers believed in CGI but were unable to implement it in the classroom due to time restraints and uncooperative mentor teachers.

Chauvot and Turner (1995) found similar results when they studied one pre-service teacher and her beliefs about problem solving. The teacher's beliefs changed from thinking problem solving was simply solving word problems (based on experiences as a student) to thinking of problem solving as a process that students use to understand mathematical concepts (Chauvot & Turner, 1995). This study's findings are, however, somewhat problematic as the teacher did not implement problem solving in the classroom due to time constraints.

In contrast, Crespo (2003) studied pre-service teachers who changed their beliefs about problem posing (providing students with multi-step problems to solve) and actually implemented the new methodology in their mathematics classrooms during student

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teaching. These pre-service teachers were enrolled in a mathematics seminar where they learned about problem posing and problem solving by actually solving problems and then discussing their strategies and solutions. Crespo (2003) concluded that this technique was the main factor causing change. Although these teachers changed their beliefs and practices while student teaching, the study did not follow them in their careers to see if their new practices were sustained.

Similarly, Timmerman (2004) found comparable results when pre-service teachers participated in a mathematics method course that incorporated three interventions: (a) problem-solving journals, (b) structured interviews, and (c) peer teaching. Like the pre-service teachers in the previous study, these teachers were also solving mathematical problems, writing thoughts in their journals, and discussing their solutions with one another. In their student teaching sites, the teachers conducted structured interviews with the students to explore their thinking and strategies while solving the problems. In addition, the teachers implemented problem-solving practices via peer teaching (three teachers worked together to plan, implement, and reflect on their teaching). As a result, the teachers' beliefs and practices shifted toward a reform-oriented mathematics education perspectives. Timmerman attributed these changes to the three interventions included in the mathematics methods course.

Overall, these studies examined how pre-service teachers were taught pedagogical content knowledge via mathematics methods courses. The researchers all explored how these courses and student teaching experiences affected teachers' beliefs and instructional practices. Some studies yielded positive results in changing the teachers' beliefs but

noted that the instructional practices did not change (Bright & Vacc, 1994; Chauvot & Turner, 1995). Another study (Benken & Wilson, 1996) found no change in teacher beliefs, but the instructional practices reflected reform-based practices. These three studies note the important relationship between espoused beliefs and actual practices. Finally, a few studies in which pre-service teachers were actually participating in the same activities that they would be teaching yielded positive changes in teachers' beliefs and practices (Crespo, 2003; Timmerman, 2004). In the end, some change was detected in all studies.

Children's mathematical thinking. A few studies (Ambrose, 2001, 2004; Lubinski, 1993; Steinberg et al., 1994; Steinberg et al., 2004) have examined how having teachers learn about and explore children's mathematical thinking can affect teachers' pedagogical content knowledge and beliefs, resulting in changes in instructional practices. According to Ambrose (2001, 2004), having pre-service teachers work one-on-one with students, providing them with specific mathematical tasks that elicited children's thinking and revealed their understanding through oral and written responses, allowed the teachers to learn about how children think and understand mathematics. As a result, these teachers' beliefs significantly changed, and this new knowledge was reflected in their instructional practices (Ambrose, 2001, 2004).

Lubinski (1993) found similar results; however, Lubinski studied experienced teachers who participated in a four-week summer workshop where they learned about the different ways that children think about and understand mathematics. After the workshop, several teachers were interviewed and observed in the classroom. The

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teachers not only changed their instructional practices but also commented on how their knowledge and beliefs about pedagogy changed directly as a result of the workshop (Lubinski, 1993). Finally, Steinberg et al. (1994) conducted a year-long case study with one experienced teacher who was implementing a reform-based teaching approach, CGI. In addition to CGI, the teacher interviewed the students. Steinberg et al. (1994) discovered that through the student interviews the teacher learned a great deal about how students think about and learn mathematics and, as a result, the teacher's instructional practices changed. In a later study, Steinberg et al. (2004) followed up with the same teacher and discovered that her knowledge and her new beliefs, and practices persisted over time.

In general, all of these studies indicated how important it is for teachers to be knowledgeable about children's thinking and understanding in mathematics. This knowledge was acquired via student teaching experiences, seminars, and interviewing children. With this new knowledge, teachers' pedagogical content knowledge, beliefs, and instructional practices changed.

Curricular influences. Many times teachers are forced to change their instructional practices because they are given new curricula. Two research studies examined teachers' beliefs and instructional practices as a result of such a change (Drake & Sherin, 2006; Hojnacki & Grover, 1992). Drake and Sherin (2006) specifically looked at how teachers implemented and adapted a reform program, *Children's Math Worlds* (*CMW*). Twenty teachers using *CMW* were studied over the course of three years. Drake and Sherin (2006) discovered that the teachers' own experiences in learning mathematics,

current perspectives of themselves as mathematics learners, family experiences, and beliefs about mathematics pedagogy influenced their implementation. These teachers did not implement the program as intended; instead they reverted to their past experiences, indicating that their beliefs and instructional practices were unchanged (Drake & Sherin, 2006).

Hojnacki and Grover (1992) explored the beliefs and practices of teachers that implemented a reform curriculum, *Thinking Mathematics (TM)*. Sixty-five teachers from kindergarten to fifth grade at five sites across the country participated in the study. All of the participants voluntarily implemented *TM* into their classrooms for the entire school year. Unlike the teachers in the previous study, these teachers were also involved in the creation of the curriculum and during implementation discussions took place between researchers and teachers. A midyear survey and an end-of-year evaluation were used to obtain the participants' perspectives on the project's impact on themselves and their students. According to Hojnacki and Grover (1992) the teachers' beliefs about pedagogy changed and they were enthusiastic about implementing the curriculum. In addition, students' academic achievement was measured using the state's standardized achievement scores to compare students taught using *TM* and those who were not. Lastly, three surveys were given to each student to gather data about their confidence in their mathematics abilities, motivation to do mathematics, and general attitudes about mathematics. After data analysis, the results showed that students' achievement and attitudes towards mathematics significantly increased (Hojnacki & Grover, 1992).

In summary, these two studies indicate that it is not enough to simply provide a teacher with a new curriculum in hopes of fostering change. Instead, teachers need to be involved in curriculum development and participate in discussions with others while implementing the curriculum.

Teacher Reflection

The last two studies focusing on teacher change involved teachers' reflection on their instruction. Artzt (1999) found through observations of pre-service teachers that the mathematics methods classes had no apparent effect on their teaching. To understand why this was the case, Artzt (1999) conducted a study in which pre-service teachers were asked to reflect on their cognitive and instructional practices before, during, and after their lessons via writing and interviews. Artzt (1999) indicated that through these reflections, she was able to understand why pre-service teachers made certain instructional decisions and therefore could provide greater assistance to them in their development as teachers. As a result, the teachers' beliefs and instructional practices changed to reflect what they were learning in their methods courses.

Similarly, Chapman (1999) asked experienced teachers to write narrative reflections about their teaching while implementing a new problem-solving instructional approach. As a result of the writing the reflections, the teachers' beliefs about incorporating problem solving changed and their instructional practices improved. In the end, these two studies reflect the importance of teacher reflection in the process of teacher change.

In conclusion, changing teachers' beliefs can lead to teacher change. Their beliefs evolve largely as a result of learning new pedagogical content in mathematics methods classes and studying children's mathematical thinking. In addition, teachers can change by implementing a new curriculum and writing down their reflections. The studies considered above have implications for future research, methodology courses, student teaching experiences, and curriculum implementation programs. More research should be conducted to study further the effectiveness of the aspects that affect teacher change discussed above. Mathematics methods classes might require pre-service teachers to reflect on their beliefs and student teaching experiences throughout the course. Student teaching experiences should have pre-service teachers focus on student learning. When implementing new curriculum, an explicit effort should be made to link the teacher's current beliefs to the new teaching methods.

Professional Development and Its Effect on Teacher Beliefs and Instructional Practices

Only a handful of studies have specifically examined the relationship of teacher change to problem-solving instruction. The majority of these studies examined changing beliefs of pre-service teachers. However, the results from these studies provide researchers and teacher educators with valuable information.

Pre-service teachers. Pre-service teachers enter their teacher education programs with little knowledge of how children think about mathematics and view mathematics instruction as simply learning basic skills and practicing those skills, a non-constructivist

perspective (Vacc et al., 1998). Researchers have found various factors that can realign these beliefs to NCTM (2000) reform standards specifically focusing on problem solving.

Several researchers have concluded that for these beliefs about mathematics instruction to evolve, pre-service teachers need experiences found in methods courses that are grounded in constructivist views that emphasize problem solving as the major means for children to learn mathematical concepts (Ambrose, 2001, 2004; Artzt, 1999; Bright & Vacc, 1994; Chauvot & Turner, 1995; Crespo, 2003; Steinberg et al., 1994; Vacc & Bright, 1999; Vacc et al., 1998). In addition, when these courses are coupled with student teaching experiences where pre-service teachers have the opportunity to observe and discuss students' mathematical thinking, their beliefs change more dramatically (Ambrose, 2001, 2004; Bright & Vacc, 1994; Vacc & Bright, 1999; Vacc et al., 1998). Such experiences include working with children one-on-one, providing mathematical tasks that elicit children's thinking, and asking critical questions to get to a fuller understanding of the reasons for their thinking (Ambrose, 2001, 2004; Steinberg et al., 1994).

Two other vital pieces that influence change are reflection and active involvement with students. Pre-service teachers need time to reflect about what they are learning, both in their methods classes and from students, as well as time to reflect after observing mentor teachers and teaching lessons themselves (Artzt, 1999). This reflection time allows pre-service teachers to make connections and build a stronger knowledge about how to best teach mathematics (Vacc & Bright, 1999). In addition, pre-service teachers need to participate in problem-solving activities similar to those that they will be using in

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the classroom (Crespo, 2003). Through these activities teachers elicit from themselves the same type of problem-solving strategies that they hope their students will use. Essential to this process is time for pre-service teachers to discuss their thinking with other colleagues and explore how this relates to children's thinking processes (Crespo, 2003). Such activities can be offered in the pre-service teachers' methods courses.

Based on the results of the above studies and through combining mathematics methods classes grounded in constructivist views, student teaching experiences, opportunities for reflection, and active involvement, pre-service teachers may come to believe that: (a) it is important to understand children's general cognitive development in mathematics and each individual child's needs, (b) children are capable of constructing their own mathematical knowledge and need to be given opportunities to do so, (c) children of all ages must be given opportunities to explore various ways to solve problems, (d) allowing children to discuss their strategies and thinking is imperative, (e) teachers need to know how to ask questions to make a child think more critically, (f) problem solving is how students learn mathematics concepts, and (g) a teacher's role should be that of a facilitator and students should take an active role in their learning (Ambrose, 2001, 2004; Artzt, 1999; Bright & Vacc, 1994; Chauvot & Turner, 1995; Crespo, 2003; Vacc & Bright, 1999; Vacc et al., 1998). Based on the NCTM's (2000) problem-solving standard, these beliefs reflect how mathematics instruction should be implemented in classrooms. The question remains: are pre-service teachers who effectively changed their beliefs able to maintain these beliefs and implement them when they make the jump to teaching in their own classrooms?

In-service teachers. Teachers have preconceived beliefs about how to teach mathematics, formed from their experiences as students, their pre-service education, past and present experiences in teaching, and professional development throughout their careers (Hojnacki & Grover, 1992). Many of these beliefs about mathematics instruction do not align with current reform standards; change is, therefore, both absolutely necessary and extremely difficult (NCTM, 1989). A few studies have examined attempts to change teachers' beliefs and instructional practices to include a problem-solving model of teaching mathematics.

Experienced teachers need courses or seminars to learn about how children think about mathematics, opportunities to work one-on-one or in small groups with students to understand how they learn, time to reflect on their instructional practices, and involvement in the development of reform curriculum (Chapman, 1999; Hojnacki & Grover, 1992; Lubinski, 1993; McGatha & Sheffield, 2006). In one study (Lubinski, 1993), teachers attended a four-week seminar that provided information about how students think and the various strategies they use to solve problems. In addition, during this seminar teachers worked together to use this knowledge to plan mathematics instruction for the following year. It was discovered that, using their new knowledge, teachers developed more awareness of children's abilities in learning mathematics. Observations made and interviews conducted during the school year indicated that this awareness affected teachers' decisions about their own classroom role, the role of their students, and the role of content. According to Lubinski (1993), changes in the teacher's learning environment encouraged student-teacher discourse, use of tasks involving

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problem solving, and on-going assessment of students' knowledge; the new environment clearly differs from the traditional mathematics classroom where the teacher provides information about how to solve problems.

In another study, teachers participated in a one-week summer camp followed by a yearlong professional development institute (McGatha & Sheffield, 2006). During the summer camp, teachers arrived an hour before students did each day and engaged in rich problem-solving tasks, which would later be given to the students. By doing the tasks themselves, the teachers were able to come up with appropriate questions to probe students' thinking. Then, the teachers stayed an hour after the students left for a debriefing session. During this time teachers discussed: (a) their own observations of the problem-solving activity and the strategies used to engage students; (b) their insights gleaned from working with a small group of students; (c) students' thinking, questioning, and problem-solving abilities; (d) strategies used to facilitate whole-class discussion; and (e) questioning techniques that encouraged student thinking. Once the summer camp was over, the teachers were challenged to begin integrating problem posing and problem solving into their classrooms as well as to keep a reflective journal of this process. Five times during the year, the teachers met and discussed their experiences. McGatha and Sheffield (2006) concluded that these experiences caused the teachers to change their beliefs and mathematical practices; some of the most influential activities were the sessions where teachers shared with one another their successes and struggles in changing their practice.

Chapman (1999) also explored the power of teacher reflection. During an entire year of implementing problem solving into their classroom for the first time, teachers wrote reflective narratives about their experiences. These reflections suggested that the teachers grew to realize how important and powerful problem solving is for students learning mathematics; as a result, they changed their instructional practices and indicated they would continue to do so (Chapman, 1999). Lastly, teachers that were involved in developing a reform curriculum focused on incorporating problem solving (*Thinking Mathematics*) were willing and able to change their instructional practices (Hojnacki & Grover, 1992).

Researchers and teacher educators should use these four studies as a jumping off point in their quests to assist experienced teachers in changing their beliefs and practices so that they can effectively include problem solving in their lessons, thereby creating a mathematics classroom aligned with current reform standards. However, four studies cannot cover everything; more research is needed.

Next Steps

Problem solving has drawn increased attention in recent years. Although many studies have looked at the effectiveness of incorporating problem solving into the classroom, there has been little research to investigate how teachers change their beliefs, knowledge, and instructional practices to include problem solving. The study presented here explored the process of teacher change that occurred when teachers participated in a year-long professional development activity where they created, implemented, and

reflected on mathematical problem-solving lessons with a focus on students'

mathematical thinking and strategies during the lessons.

CHAPTER 3: METHODOLOGY

This chapter is divided into two sections, the research study and research design. The first section will discuss the research questions that guided the study, the participation selection process, the participants, the research site, and the researcher's role. The second section will describe the implementation and procedures of the PLC and problem-solving activities, development of the problem-solving activities, participants and details of the PLC meetings, the data collection procedures, the data analysis techniques, and validity.

The Research Study

Research Questions

The research questions addressed by this study include:

1. How do two grade six teachers respond to a problem-solving based professional learning community (PLC)?

    a. Do these teachers' beliefs/perceptions/insights change, if so, in what ways?

    b. Do these teachers' instructional practices change, if so, in what ways?

2. What influences these teachers' decision making throughout the year?

3. What are the decision-making practices of a teacher leader?

Participant Selection Process

Before the study began, I had been a fifth-grade teacher at the research site for four years (2003-2007). In addition, during the 2006-2007 school year, I had led a small professional learning community (PLC) group focused on mathematics teaching and learning, comprised of a small group of upper elementary mathematics teachers. During these monthly, two-hour meetings, we discussed and researched areas in mathematics teaching and learning that we wanted to further explore and share with other staff members, such as mathematics literacy. As a result of this teaching and leading the PLC, I had developed a working relationship with the teachers at my school. Given these relationships and knowing that our PLC would continue the following year, I decided to seek teacher participants for this dissertation study from this school.

To recruit participants, I first discussed the possibility with the principal and then followed up the conversation with a formal letter describing the research study, involvement of the participants, and potential gains to both the teachers and school from participation. After the principal gave her approval, I spoke to two fourth-grade teachers and two sixth-grade teachers, providing each of them with a similar letter. (I chose fourth- and sixth-grade teachers because I was a fifth-grade teacher.) At the end of the 2006-2007 school year, three teachers had agreed to participate (two sixth-grade teachers and one fourth-grade teacher). However, by the beginning of the 2007-2008 school year one of the sixth-grade teachers had accepted a job elsewhere and the fourth-grade teacher had moved to sixth-grade. Therefore, despite my intentions to have some variety in grade levels, my participants were two sixth-grade teachers.

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Participants

Both of the participants, Emma and Cathy (pseudonyms), were sixth-grade

mathematics and science teachers. During the research study, both participants were

relatively new to teaching: it was Cathy's third year of teaching (two years prior

experience as a fourth-grade teacher) and Emma's fourth year of teaching (three years

prior experience as a sixth-grade science teacher in a middle school). Both participants

taught two mathematics classes each day. I chose to observe only one class for each

teacher based on my own teaching schedule. I observed Emma's class of sixth-graders of

mixed ability levels learning sixth-grade math. I observed Cathy's class of sixth-graders

learning seventh-grade math; these students had more advanced mathematics knowledge

and skills than the students in Emma's class. I purposely chose these classes to see if the

students' different academic levels might yield different results. More detailed

descriptions of both participants are provided in response to the first research question.

Research Site

The study was conducted at a public elementary school located in a mid-size

suburban area in Northern Virginia. The school served 936 students in grades

kindergarten through sixth, of which 12% received free and reduced lunches. Fifty-six

percent of the students were Caucasian, 25% were Asian, 8% were Hispanic, 3% were

African American, and 8% were listed as other. For the 2007-2008 school year,

approximately 95% of the student population passed all the state standardized

accountability exams, with a 92% passing rate in mathematics. The school's staff

consisted of one principal, two assistant principals, 67 licensed teachers, 21

paraprofessional classroom aides, two guidance counselors, six custodians, and six office support workers. The school day lasted for approximately seven hours Tuesdays through Fridays and four hours on Mondays. In grades kindergarten through fourth, the students had one teacher that instructed them in language arts, mathematics, science, and social studies. The teachers in fifth and sixth grade were departmentalized, meaning the students had one teacher for math and science and a different teacher for language arts and social studies. In addition to this core curriculum, students had classes in general music, health, physical education, art, computers, and Italian.

Researcher's Role

As the researcher, my role had four tasks. First, I facilitated all of the PLC meetings. This function entailed providing information to the participants about problem-solving activities, keeping the meetings on-task and progressing along the intended agenda, and mediating discussions where the participants reflected upon their implementation of a problem-solving activity as well as analyzed their students' thinking processes as they completed the activities. Second, I supported the teachers in creating problem-solving activities by providing resources including examples of problem-solving activities and suggestions for how to modify existing activities to meet their new needs. As the year progressed the teachers needed less and less support. Third, I participated fully in the PLC meetings, because I too implemented problem-solving activities in my two fifth-grade mathematics classes. Fourth, I served as the researcher. I interviewed the teachers and transcribed the interviews; I observed the teachers teaching mathematics

lessons as well as when they implemented three problem-solving activities; I videotaped

PLC meetings and transcribed these tapes; and I analyzed all the data.

Research Design

This was a qualitative design study using a multi-tiered professional development

design (Zawojewski, Chamberlin, Hjalmarson, & Lewis, 2008). In this type of design

study teachers, researchers, and facilitators work collaboratively to design educational

objects in a professional development-like setting. Specifically, teachers develop lessons

that will be used in the classroom. These lessons are tested (i.e., used in the classroom)

and revised. Throughout this process of lesson development, testing, and revision

teachers have opportunities to express their ways of thinking about teaching and learning

as these relate to the lesson. In short, teachers externalize aspects of their interpretive

systems (Zawojewski, et al., 2008). The facilitator and researcher (these two roles can be

carried out by the same person) examine the teachers' interpretive systems. Further, the

facilitator is responsible for designing subsequent professional development sessions; the

researcher works with the facilitator in this process, but also attempts to develop a theory

for designing experiences to prompt teacher growth (Zawojewski, et al., 2008). Students

are the main focus of all three constituents because they are all concerned with students'

thinking and aim to change or improve students' thinking (Zawojewski, et al., 2008).

Implementation Design and Procedures

The implementation design for this study has two main parts: (a) a problem-

solving based professional learning community (PLC), and (b) implementation of

problem-solving activities by the two participants. Before launching the PLC meetings

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(where problem-solving activities were created and discussed) and implementing

problem-solving activities, I gathered information about the two participants. In early

October I observed each participant teaching a mathematics lesson so that I could get an

idea of their instructional practices and implementation of a lesson. Shortly after the first

observation, I conducted a pre-interview to understand each participant's beliefs,

knowledge, and instructional practices about teaching and learning mathematics as well

as their understanding of problem solving. (See Appendix A for the pre-interview guide.)

After I gathered that information, we had our first PLC meeting where I provided the

participants with information about problem solving and explained the goals for our PLC.

(A detailed account of each PLC meeting is provided in chapter four).

After the first PLC meeting, I again observed each participant teaching a

mathematics lesson so that I could compare their actual teaching with what they had

described in the pre-interview. We then continued with four more PLC meetings,

punctuated with three more observations of each participant implementing problem-

solving activities into their respective classrooms. In April 2008, I observed each

participant one last time during a lesson of their choosing. Finally, I conducted a post-

interview in May to gather information about their beliefs, knowledge, and instructional

practices in mathematics teaching and learning that I could then compare with the pre-

interview information. (See Appendix B for the post-interview guide.) Table 1 lists the

dates of interviews and observations for each participant, as well as the dates of each PLC

meeting.

Table 1

Timeline of Interviews, Observations, and PLC meetings

	Emma	**Cathy**
Observation 1: Math lesson	October 5, 2007	October 4, 2007
Pre-Interview	October 8, 2007	October 12, 2007
PLC Meeting 1	October 15, 2007	
Observation 2: Math lesson	November 9, 2007	November 8, 2007
PLC Meeting 2	November 19, 2007	
Observation 3: Problem-solving lesson	December 4, 2007	December 7, 2007
PLC Meeting 3	January 7, 2008	
Observation 4: Problem-solving lesson	January 16, 2008	January 24, 2008
PLC Meeting 4	February 11, 2008	
Observation 5: Problem-solving lesson	April 2, 2008	March 13, 2008
PLC Meeting 5	April 21, 2008	
Observation 6: Math lesson	April 30, 2008	April 17, 2008
Post-Interview	May 12, 2008	May 19, 2008

Development of Problem-Solving Activities

My original plan was to design problem-solving activities during the PLC meetings with the participants using the principles for designing productive model-eliciting activities described by Lesh et al. (Lesh, Hoover, Hole, Kelly, & Post, 2000). Model-eliciting activities (MEAs) are, in essence, problem-solving activities; however, these particular activities are designed to—as the name indicates—elicit student's thinking. According to Lesh et al. (2000), model-eliciting activities involve students interpreting mathematically a complex real-world situation and require the formulation of a mathematical description, procedure, or method (e.g., a model) that reveals students' thinking and solution. These activities have been found to improve students' *and*

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teachers' learning. The authors assert that the most effective way to support teachers in improving their teaching practices is by helping them become more familiar with their students' ways of thinking and model-eliciting activities do just that (Lesh et al., 2000).

However, it became clear that creating MEAs was too ambitious of a task for us to accomplish three times during the five PLC meetings set up throughout the year. As a result, we used the resource *Children Are Mathematical Problem Solvers* (Sakshaug, Olson, & Olson, 2002) and the six design principles for creating model-eliciting activities (Lesh, et al., 2000) as guides.

In *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002) the authors provide 29 problem-solving situations designed to engage students in thought-provoking explorations where they do challenging, interesting problem solving with significant mathematical content. Our PLC chose several of these problem-solving activities that we thought were appropriate for our students and modified them to follow the six principles explained below. As the leader, I pointed out several problem-solving activities that I thought would be appropriate; then I facilitated participants' discussion of how to adapt the activities.

The six design principles included the: (a) Model Construction Principle (requires that students to construct an explicit description, explanation, or procedure for a mathematically significant situation); (b) Reality Principle or Meaningfulness Principle (ensures that the activity can be interpreted by students using their various levels of mathematical ability and general knowledge); (c) Self Assessment Principle (ensures that the activity contains criteria the students themselves can identify and use to test and

revise their thinking); (d) Construct Documentation Principle (requires students to create some documentation for revealing their thinking); (e) Construct Shareability and Reusability Principle (requires students to create solutions that can be used by others and with other problems); and (f) Effective Prototype Principle (ensures that students' solutions will be as simple as possible yet still mathematically significant) (Lesh, et al., 2000).

Using these principles to modify existing problem-solving situations helped the PLC team participants develop problem-solving activities that effectively elicited student thinking and therefore allowed the participants to easily observe, record, and reflect on their students' thinking and strategies.

A Problem-Solving Based Professional Learning Community

At the research site, all teachers were required to participate in a PLC group. I led the PLC group focused on mathematics teaching and learning and the other members voluntarily choose this group. Our PLC consisted of the two participants in this study, Emma and Cathy, a fifth-grade teacher, a fourth-grade special education teacher, and me. We met five times during the year for approximately two-hour sessions. The purpose of these meetings was to design problem-solving lessons for classroom use as well as to provide a place for the teachers to discuss and reflect on the implementation of these problem-solving activities, the effectiveness of their teaching, their students' thinking, and so forth. However, after gathering information from the two participants, I realized the members needed further information and resources about problem solving before we could begin.

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Guided by the group's needs, I, as PLC leader, decided to provide the participants with information during the first meeting on October 15, 2007. I endeavored to widen their understanding of problem solving by discussing the NCTM definition of problem solving and the effectiveness of implementing problem solving into the classroom and by giving examples of problem-solving activities. Participants then talked over the new information and were excited to begin creating problem-solving activities for the next meeting.

During the second meeting on November 19, 2007 the group looked through the book *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002), which has 29 problem-solving situations. Members agreed on one problem-solving activity that we then modified to align with the six design principles. (See Appendix C for this activity.) Both participants implemented this activity prior to the next meeting in classes that I observed.

On January 7, 2008 during our third PLC meeting all members discussed their implementation of the first problem-solving activity. The members shared their reflections on their own teaching processes during this activity; they also described the various strategies their students used to solve the problem. In addition, the PLC members discussed ways to modify this activity for younger (primary grades) and older (middle school grades) students. At the end of the meeting, it was decided that each member, individually, would choose and implement another problem-solving activity, modifying it to fulfill the six design principles. Each of my participants implemented her second problem-solving activity prior to the next meeting in a class that I observed.

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The fourth meeting, on February 11, 2008, was almost identical to the third; the members shared their problem-solving activities, their teaching processes, the students' strategies, modifications made to the activity, and so on. Again, all members agreed to choose and modify another problem-solving activity and to implement it prior to the last meeting. I again observed my two participants.

The last meeting, held on April 21, 2008, was identical to the two prior meetings. Members shared their teaching process, thoughts, and observations. To conclude for the year I discussed how much progress the group had made throughout the year. The members' final task was to revise both of the problem-solving activities they had used, based on their thoughts and observations while implementing it as well as the feedback received during the PLC meetings. In addition, they were asked to create a "teacher page" where they would suggest ideas for implementing the activity, possible manipulatives and tools that could be available for the students, and modifications and extensions for learners of various ages. We decided to compile all of the problem-solving activities we had used into one electronic document. The group would share this compilation with the rest of the staff during a staff development meeting the following school year in November 2008.

Data Collection Procedures

Data for this study was collected in three phases. During Phase 1 (October and November 2007), I gathered information about each teacher's beliefs, knowledge, and instructional practices with regards to teaching and learning mathematics as well as their understanding of problem solving. To do this, I observed each teacher during two

mathematics lessons to understand how they conducted their mathematics classroom. I

took notes during the observations describing what was going on, how the classroom was

set up, instructional style, instructional materials, etc. Between the two observations, I

conducted a pre-interview with each participant. I first observed Cathy and Emma before

the pre-interview and again after the pre-interview to determine if what they had

described in the pre-interview was actually taking place in the classroom. The interviews

were audio taped and transcribed. The data collected during the pre-interviews and two

observations (per participant) were used to answer research questions 1 and 2.

Phase 2 of data collection involved everything that was done to incorporate

problem solving into the classroom and lasted from October 2007 to April 2008. All five

of the PLC meetings were videotaped. I took notes during the meetings and then watched

the videotapes, taking more notes and transcribing sections where the participants were

contributing to the discussions. The meetings took place on October 15, November 19,

January 7, February 11, and April 21. During the meetings, any of the following activities

could occur, based on teachers' needs: (a) as leader, I delivered professional development

about problem solving (what does problem solving in the mathematics classroom look

like, why is it important, should teachers incorporate it into the classroom, what do

problem-solving lessons consist of, how do children think about, understand, and learn

mathematics, etc.); (b) the teachers designed/modified problem-solving activities; and (c)

the teachers reflected on and discussed the implementation of problem-solving activities.

In addition to the meetings, data collection during Phase 2 included three observations of

each participant while they implemented the group-created problems-solving activities

into their mathematics classroom. Written observational notes were taken for all

observations. All of these data were used to answer research questions 1 and 2.

During the last part of data collection, Phase 3, I gathered information about each

teacher's beliefs, knowledge, and instructional practices with regard to teaching and

learning mathematics and problem solving, thoughts and perceptions about the PLC, and

plans for teaching mathematics in the future. To do this, in May 2008, I conducted a post

interview with each participant. The interviews were audio taped and transcribed and

used to answer research questions 1 and 2. Table 2 illustrates each data source and its

relationship to the study's research questions and data analysis procedure.

Table 2

Research Questions, Data Collected, and Data Analysis.

Research Question	Data Collection	Data Analysis
How do these teachers respond to a problem-solving based professional learning community (PLC)?	1. Pre-interview (Sept. 2007)	1. Qualitatively analyzed to understand teachers' knowledge, beliefs, and instructional practices and to determine where to start PLC
a. Do these teachers' beliefs/perceptions/ insights change, if so, in what ways?	2. Classroom Observations (Sept. 2007)	2. Qualitatively analyzed and summarized in a descriptive vignette
b. Do these teachers' instructional practices change, if so, in what ways?	3. Videotapes and Observations during PLC Meetings (Oct. 2007-April 2008)	3, 4, 5, & 6. These data were qualitatively analyzed using coding and connecting strategies and by making comparisons throughout to understand how the teacher responded to
	4. Videotapes and Observations of Problem-Solving Lessons (Nov. 2007-April 2008)	

	5. Informal Interviews (Oct. 2007-April 2008) 6. Post Interview (May 2008)	problem-solving PLC. Data analysis systematically occurred at three specific times: end of November, end of February, and end of May
What influences these teachers' decision making throughout the year?	1. Pre-interview (Sept. 2007) 2. Videotapes and Observations during PLC Meetings (Oct. 2007-April 2008) 3. Informal Interviews (Oct. 2007-April 2008) 4. Post Interview (May 2008)	Same as above
What are the decision-making practices of a teacher leader?	Journal (throughout)—written accounts of the entire process based on observations and procedures during PLC meetings, formal and informal interviews with individual teachers, and classroom observations	Qualitatively analyzed at three times—end of November, end of February, and end of May

Data Analysis Procedures

Since this study spanned an entire school year, data analysis was done

systematically throughout and cyclically with data collection. The interviews,

observations, and videotapes were analyzed using qualitative methods (Maxwell, 2005).

The next section first explains the data collection sources used in analysis during the

three phases and how the information was used. Next, I describe the detailed analysis

process for all data sources.

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Data analysis during the three phases. During Phase 1 of data collection, the pre-interviews were analyzed qualitatively to understand what these teachers knew and believed about teaching and learning mathematics as well as what their instructional practices were. This information was used to help me, the teacher leader, determine what topics needed to be discussed during the first PLC meeting. The classroom observations were used to write a descriptive vignette of each teacher's mathematics classroom and lessons.

During Phase 2, qualitative data analysis of all data occurred three times throughout (roughly once each quarter). This regular analysis helped inform me of the direction in which the group needed to proceed, as well as to document a teacher's changes, if any. The videotapes of all the PLC meetings enhanced the written observations made during the meetings. I wrote up final observations describing what went on during each meeting, including the procedures and the conversations as well as any interpretations that I made. For the classroom observations of the problem-solving lessons, I prepared a final written observation for each teacher and analyzed these qualitatively, looking for similarities, differences, and themes between the different teachers. I transcribed the informal interviews and analyzed them qualitatively to gauge how the teachers were responding to the professional development and determine how to proceed. Lastly, I kept a journal throughout, documenting my actions and what influenced my decisions.

Next, I analyzed qualitatively the data collected during Phase 3, proceeding, in general, as I had for the Phase 1 data. Finally, I analyzed all data collected throughout the

year comparatively, looking for any changes that may have occurred within and between the teachers as a result of this problem-solving based PLC.

Interview qualitative analysis. I used qualitative analysis to explore the participants' detailed responses to the interview questions. Prior to interviewing the participants, I had created organizational categories. According to Maxwell (2005), "organizational categories are broad areas or issues that you establish prior to your interview" and which "function primarily as 'bins' for sorting the data for further analysis" (p. 97). These organizational categories were used to create the pre-interview questions. An example of such an organizational category was "planning a mathematics lesson."

The pre-interview for each participant was audio recorded as well as scripted while the participants spoke. The audio recordings were then transcribed. The scripts made during the interviews were used as memos (Maxwell, 2005). After completing a transcription, I listened to the recordings again and checked the transcriptions for accuracy. I then reread both interviews a third time to form a complete picture of each participant. To ensure accuracy, I used "member checking" where the participants were given a chance to read and check the transcribed interviews (Maxwell, 2005).

Next, I performed open coding by hand during the second and subsequent readings to develop substantive categories (Maxwell, 2005). Substantive categories are a "description of participants' concepts and beliefs" (Maxwell, 2005, p. 97) and can be either emic—"taken from [the] participants' own words and concepts" (p. 97) or etic— which "usually represent[ing] the researcher's concepts…rather than denoting

participants' own concepts" (Maxwell, 2005, p. 98). Some emic codes included participant words or phrases such as "hands-on approach" and "word problems," while etic codes included "planning and instruction."

After identifying the substantive categories (school experiences, student learning, planning and instruction of mathematics lessons, decision-making influences, and incorporation of problem solving), connecting strategies were used to analyze the data across the two participants to look for common themes (Maxwell, 2005). The same qualitative analysis was used for both post and pre-interviews. However, since I had already established substantive categories from the pre-interviews, I was able to use these categories for the post-interview analysis to explore whether changes had occurred. In addition, I used open coding to develop any new substantive categories that emerged.

Observation qualitative analysis. I used qualitative analysis to explore participants' actions during my observations of the mathematics lessons. During all of the observations, which included both regular mathematics lessons and problem-solving lessons, I took observational notes. In addition, I wrote memos and reflections. I used my observations from the regular mathematics lessons to determine if instructional methods mentioned during the pre-interview were actually carried out. Lastly, I connected and compared my observational notes from all lessons as well as the written memos and reflections to the interview data to add greater depth to themes that emerged (Maxwell, 2005).

Video qualitative analysis. I used qualitative analysis to explore the detailed discussions that occurred amongst the participants and other members during the PLC

meetings. All five PLC meetings were videotaped. I watched each videotape took observational notes. These notes included descriptions of what took place during the meetings (e.g., planning a problem-solving activity, participants actions) as well as transcriptions of participant comments. In addition to making observational notes while watching the videos, I also wrote memos and reflections. Finally, I connected and compared my observational notes and memos from the videotapes to the interview data and my observational notes and memos from the classroom observations to add greater depth to themes that emerged (Maxwell, 2005).

In conclusion, although there were some variations in the analysis of the three different types of data collection sources, it is important to note that analysis occurred systematically throughout the entire year. No single form of data collection stood alone. Rather, all three were interwoven to provide a complete picture of each participant and to document her journey during the time covered by the study. This process was essential in exploring changes each participant may have undergone.

Validity

Several steps were taken to ensure validity of the data. Interviews were audio taped and then transcribed. After completing the transcriptions, I listened to the audiotapes again, to double-check that the transcriptions faithfully captured the participants' words. As a last step, each participant checked her transcript for accuracy.

I videotaped all PLC meetings so that I would be free to participate fully in the meetings and would not be distracted by trying to observe and take notes. I watched the videotapes and took notes describing the events of the meetings. I also transcribed any

discussions I deemed important. I watched the videotapes several times during my
analysis and write-up of the findings to ensure accuracy.

Finally, I took notes during all classroom observations of mathematics lessons. I described the physical set-up of the classrooms, the participants' actions during the lessons, the materials used, the number of students, the students' actions, any relevant discussions that occurred, and so on. I referred frequently to my notes during analysis and the write-up of my findings to insure accuracy.

CHAPTER 4: RESULTS: PART I

This chapter includes a description of each participant, the events and discussions that took place during the professional learning community meetings, and the observations made while the participants taught various mathematics lessons. It is divided into three sections: (a) Pre-Professional Learning Community, (b) Incorporation of a Problem-Solving Based Professional Learning Community and Problem-Solving Lessons, and (c) Post Professional Learning Community. In the pre-PLC section, each participant's beliefs, knowledge, and instructional practices are described based on the data collected from the pre-interview and two classroom observations. In the second section, all of the events and discussions from the five PLC meetings as well as the observations concerning the three problem-solving lessons that both participants implemented are explained. Finally, in the last section, post-PLC, each participant's beliefs, knowledge, and instructional practices are again described based on the data collected from the post interview and a final classroom observation.

Pre-Professional Learning Community

From the pre-interview and two classroom observations of mathematics lessons, data were gathered about each participant's beliefs, knowledge, and instructional practices with regard to mathematics teaching and learning. Five categories emerged from the data analysis: school experiences, student learning, planning and instruction of

mathematics lessons, decision-making influences, and incorporation of problem solving. Following is a description of these five categories for each participant. Gaining an understanding of each participant's beliefs, knowledge, and instructional practices was essential prior to beginning the professional learning community meetings and necessary for determining if the participants changed in any way as a result of the meetings.

Emma

Emma was a sixth-grade math and science teacher in a Northern Virginia elementary school. It was her fourth year of teaching and prior to this year, she had taught sixth-grade science for three years in a middle school. Each of her two mathematics classes had approximately 25 students with mixed abilities. Both classes were learning sixth-grade mathematics content based on the Virginia Standards of Learning (SOLs). The observations throughout this study pertain to Emma's afternoon class only. Emma's initial beliefs, perceptions, and insights about teaching and learning as well as her instructional practices emerged during a pre-interview and two classroom observations in October and November 2007.

School experiences. Emma's school experiences with mathematics were "mostly positive." She stated that mathematics did not come easily; it took her longer than others to understand a concept but she "got it in the end." Visual representations were the best way for Emma to fully understand concepts such as division, multiplication, and fractions. In understanding that she needed these visual representations of concepts, Emma realized that she was a different learner from others. Other students "needed more auditory, written expressions" and "visuals confused them at times." According to

Emma, this self-knowledge has enabled her to plan lessons and instruct her own students appropriately.

Student learning. During the pre-interview, Emma shared her beliefs about what students need to best learn mathematics. Emma first mentioned connecting mathematics to the students' lives via application. She believed that it was very important for students "to get the big picture" and that this could be done by applying mathematics concepts to real life, which allows students to understand why they are learning these concepts at their grade level. Emma felt that if a teacher could accomplish this goal then students "have a better chance of being interested [in] and less frustrated" with mathematics.

Second, in addition to connecting mathematics to students' lives, Emma believed that students need to be engaged and feel ownership of their learning. To Emma, being engaged means having all students participating, either individually or in small groups, using manipulatives. This practice will get the students' "blood flowing" and they will be ready to learn. Mathematics field trips are one example of how Emma believed students can take ownership of their learning. During these field trips, the students "…actually go outside, make their problems, gather information from real-life scenarios, take pictures, and then share their products with the class." As a result, Emma becomes a facilitator, the students are engaged and not just solving a problem, but understanding it conceptually.

Emma pointed out two final elements: student learning styles and assessments. Emma recognized that she had students with various learning styles in her classroom. As a result, she believed that manipulatives and other visuals should be used in addition to

written and oral explanations. She believed that if she incorporated all of these different

materials her students would have access to the same information kinesthetically,

visually, orally, and in writing. Lastly, according to Emma, students need to be assessed

not only via formal tests, but also "periodically through little mini assessments." These

mini assessments allowed Emma to gather information from the students about what

concepts they had grasped and what concepts might still be causing confusion. The

information she gathered drove her instruction.

While observing Emma teach two lessons, one in October and the other in

November, I could see no evidence of her beliefs about the important features of a lesson

that ensure student learning (related to real life; engaging; foster student ownership of

learning; include manipulatives; and have informal, mini assessments), For the most part

students were sat at their desks listening to Emma and then independently practiced the

concept just introduced. In this style of teaching, the students did not appear engaged,

were not asked to relate their learning to their lives, and they did not use manipulatives.

Some obstacles that Emma spoke about during the pre-interview may explain why she

had difficulty putting her beliefs into practice: a relatively new curriculum, lack of

resources and time, SOL pressures, and reliance on the textbook, which lacks engaging,

inquiry-based lessons.

Planning and instruction of mathematics lessons. In planning lessons, Emma

said she relies primarily on the textbook. She teaches all twelve chapters, not necessarily

in order, but based on what she thinks appropriate for a specific time. She also

sometimes plans with another sixth-grade math and science teacher, Cathy (the other

participant), and researches the Internet for other mathematics lessons. Her past experiences as a mathematics student and as a student in mathematics methods coursework, as well as her students' academic levels and SOL requirements influence her mathematics planning and instruction. Emma follows a specific format in planning and instructing for each chapter: "homework review, warm-up, lesson activity, and closure" and assesses her students at the end of each chapter using a twenty-question open-ended test created by the textbook's publishers.

Emma said she assigns homework every night because she believes that mathematics is something "the students need to practice in order to understand" and this practice should occur daily. These homework assignments are in a workbook developed for the mathematics textbook Emma uses. Each page is divided into three sections: (a) computational problems practicing the mathematics concept learned that day, (b) two or three word problems that require using the new concept to solve a real-life example, and (c) a review section with several computational questions, which reassess mathematical concepts learned earlier in the year.

Emma stated that the homework review usually lasted about ten minutes and that this was a way to informally assess the students' understanding of the concepts taught the previous day. She also said that sometimes this review took longer if she discovered that the students really had not understood the previously taught concept. While Emma stated that she used the homework review to informally assess the students, in an observation of one class session, however, I noted that the homework review did not accomplish this goal. Emma gave the students the answers to their homework so they could self-correct.

Emma did not walk around the room during this particular lesson to gauge student comprehension; she only went over a problem if a student asked a clarification question. During this lesson, I observed that several students who did not answer questions correctly did not ask for explanations.

According to Emma, after the homework review she conducts a warm-up activity to introduce the concept she will be teaching that day. Emma stated that these activities often involve the use of manipulatives like dice and/or spinners and can be completed by an individual student or in a small group. Emma gave an example of such a warm-up activity from her order-of-operations lesson: The students used two spinners, one with numbers, and the other with operations. The students took turns spinning in to create a multiple operation equation. After each student solves the equation, they compare answers and discover they have come up with different answers. This realization allows the students to understand the reasoning behind having a set of rules for solving equations; the Order of Operations. During the two lessons I observed in the beginning of the year, no warm-up activity was used.

Emma indicated that the bulk of her mathematics instruction is devoted to the lesson activity, which generally lasts between 25 and 35 minutes; she starts this activity by giving the students an algorithm to solve the mathematics problem. According to Emma, during this time the "students are in their seats with their books out, going through the lesson" in the textbook. I observed during the two lessons in the beginning of the year that the algorithm was introduced in different ways: (a) writing the algorithm or steps on the board and providing examples, (b) giving the students the algorithm and then

showing them how to apply it using manipulatives, or (c) using technology such as a SMART Board to display the algorithm and go through examples. This delivery was consistent with Emma's description of the lesson activity portion of her lesson; she stated the algorithm and manipulated it visually. After the algorithm was given, students generally practiced independently by completing several mathematics problems. Next, the students came up to the board and showed how they had solved the problem while orally explaining their procedures.

Emma also incorporated visuals into the lesson activity during both observations, For example, during the first observation while Emma went over long multiplication she used three different colors to represent the ones, tens, and hundreds digits. As she mentioned earlier, visuals were an important piece in her own learning of mathematics and, as a result, she incorporated them into her lessons. Finally, according to Emma's interview, the mathematics lesson concluded with a short closure portion. As observed in the two lessons, this closure was a time for students to ask questions about what they learned or Emma would review that day's algorithm and/or explain that night's homework.

Decision-making influences. While talking about her planning and instruction in mathematics, Emma mentioned some of the influences on her decision-making processes. She stated that she was most influenced by the SOLs created by the Commonwealth of Virginia, as these addressed what her sixth graders were required by the state to learn in mathematics. Next, Emma said she thought about her students' academic levels and learning styles. This assessment helped her decide if she needed to incorporate more

visual and hands-on materials. She also discussed trying to integrate other subjects into mathematics, especially science since that was the other subject she taught. She liked to show the students how science, language arts, and history can involve mathematics. Emma claimed that "it helps the students see that the subjects are related" and do not just stand alone. Lastly, since this was Emma's first year teaching mathematics she explained that "she does not have a lot of resources to pull from" and therefore she relied heavily on the lesson plans in the textbook's teacher's manual. However, she did mention that once she started teaching, the student feedback might lead her to modify how she delivered the lesson or the lesson content.

Incorporation of problem solving. During the pre-interview, Emma discussed how she incorporated problem solving into the classroom. She defined problem solving as working through word problems using various strategies. Each chapter in her textbook included two problem-solving lessons and she taught these lessons at the end of each chapter. These lessons taught students one strategy that could be used to solve various word problems. Emma considered these to be "enrichment activities" and felt that they "take longer because there is reading involved." Two examples Emma mentioned were guess and check and using pictographs. In addition to these problem-solving lessons from the textbook, the students did a couple of word problems as part of their homework assignments each night, as well as during their chapter assessments. (Both the homework assignments and assessments are generated by the textbook publisher.)

Summary of beliefs, perceptions, and instructional practices. Emma's interview revealed several beliefs about teaching and learning mathematics that align

with the reform view of teaching mathematics. Such beliefs include using manipulatives

and visuals to help students conceptually understand a mathematics concept, allowing

students to be actively engaged and take ownership of their learning during mathematics

lessons, and relating mathematics concepts to their own lives (Collier et al., 2002; Drake

& Sherin, 2006; Fennema et al., 1996; Fernandez, 1997; Vacc & Bright, 1999; Vacc et

al., 1998). Despite these stated beliefs, analysis of the observation data indicated that

Emma's instructional practices followed a more traditional view of teaching

mathematics: (a) teaching directly from a published textbook, (b) providing the students

with an algorithm or set rules to understand a mathematical concept, (c) having students

seated at their desks, textbooks open, listening to the teacher, and (d) incorporating

problem solving solely by using word problems that require students to use only one

strategy for all of the problems (Bright & Vacc, 1994; Capraro, 2001; Chapman, 1999;

Chauvot & Turner, 1995; Crespo, 2003; Ford, 1994; Gravemeijer, 1997; Millard, et al.,

2002).

Cathy

Cathy was also a sixth-grade mathematics and science teacher in the same

Northern Virginia elementary school as Emma. This was her third year of teaching and

prior to this year, she had taught all subjects in a fourth-grade classroom for two years.

Although Cathy was a sixth-grade teacher, she taught two very different classes: her

morning class was sixth graders learning sixth-grade mathematics content, while her

afternoon class was sixth graders learning seventh-grade mathematics content for.

Throughout this study I observed Cathy's afternoon class—students with above-average

mathematics knowledge and skills. In addition to teaching, Cathy was the mathematics lead teacher for her elementary school, which required her to meet once a month with all the other math lead teachers from her cluster (the school district that Cathy taught in was so large that it was divided into seven smaller sections called *clusters*) as well as leading people involved in mathematics instruction, curriculum, and assessment development in her district. Cathy's initial beliefs, perceptions, and insights about teaching and learning as well as her instructional practices emerged during a pre-interview and two classroom observations in October and November 2007.

School experiences. Like Emma, Cathy's school experiences in mathematics were positive. Although she did not have clear memories of her elementary school classes, she did remember "doing things in groups" and "taking a lot of notes" in middle school and high school. Cathy did not really recall her teachers' specific instructional practices, but did remember what they did *not* do. She stated: "I try to take on a more hands-on approach" to teaching and show "multiple ways to do a problem because I don't think that was emphasized when I was in school." Cathy stated that, for her, the "paper-pencil method" worked best, but that other strategies should be presented because "everyone learns differently." Despite Cathy's claim to remember little from her school experiences in mathematics, the few memories she did have appear to have influenced her beliefs and instructional practices in teaching and learning mathematics.

Student learning. During the pre-interview, Cathy shared her beliefs about how students learn best in the mathematics classroom. The first factor that she mentioned was practice. Cathy felt that sometimes students "can't get any better at math unless they

practice." Cathy's idea of practice could be as simple as a homework assignment with several mathematics problems reviewing what students learned in class that day. In addition, Cathy said the students practice during her mathematics lessons by doing independent work, working in groups, playing games, and/or applying their new knowledge to real-life scenarios. She discussed an example involving decimals, noting that often "the students do not really understand the concept of decimals, or the value of a decimal," so an activity involving money helped students grasp the concept. They learned that one decimal place makes a significant difference, for example, "$.06, $.60, and $6.00."

Besides practice, Cathy felt that providing students with note pages on each mathematics concept was imperative because it gave them something "to refer back to." The note pages were like review sheets, breaking down the steps for solving a problem; they also included a few problems for students to practice by applying those steps. After reviewing the note pages, she claimed that it was also important to explain to the students "why they are learning the concept and why it is useful." Cathy stated that this explanation helped motivate the students to learn the given concept.

Practice and note pages were the two main tools that Cathy discussed when asked how the students best learned mathematics. However, in answering other questions throughout the interview, Cathy said that it was important to incorporate hands-on activities during lessons (as a way to practice in a different way) as well as to provide students with various problem-solving methods in recognition of students' different learning styles.

While observing Cathy teach two lessons, one in October and one in November, I noted that she put into practice everything that she had spoken about in the interview. She either provided the students with a note page or had the students copy specific notes into their notebooks. The students also practiced what they had learned via independent work or group work. All practice problems were related to real-life scenarios. Additionally, each lesson ended with a game that either reviewed a previously learned concept or the concept introduced that day. Lastly, throughout Cathy's lesson, she provided the students with different ways of solving the same problem or had the students share the various strategies that they used. Overall, Cathy's beliefs about student learning were reflected in the two observed mathematics lessons.

Planning and instruction of mathematics lessons. In planning lessons, Cathy stated that she relied primarily on the district's pacing guides to determine what mathematics concepts to cover during the year and when. Once she had established which concepts to teach, she chose appropriate chapters in the textbook. She was aware that some teachers did not use a textbook, and explained "I do not feel comfortable, perhaps because I am still a newer teacher, with just throwing out the textbook altogether." Instead, she used the textbook to structure her lessons, but pulled from various resources to supplement what she was teaching and provide more hands-on activities and real-life situations. Her belief in using these additional materials came from learnings in her mathematics methods class in graduate school. As a result, it appears that Cathy did not rely as heavily on the textbook as did Emma. However, like Emma, Cathy still followed a specific structure when planning and implementing her math lessons: homework

review, warm-up, lesson, and independent or group practice. To assess students, Cathy gave the students an end-of-the chapter test, developed by the textbook publishers, consisting of 20-40 open-ended questions.

Cathy stated that she assigned homework to her students every night because, like Emma, she believed that students needed to practice the mathematics concepts introduced that day to learn them. The homework assignments were workbook pages corresponding to the textbook and to the lesson/concept taught that day in class. Each assignment page was two-sided, with examples and explanations about the concept as well as a few practice problems on the front and, on the back, practice problems that usually increased in difficulty and required application rather than just rote drill and practice. Cathy reviewed the homework assignments at the beginning of class the next day. She provided the answers and the students could then ask questions. I noted during my two observations of Cathy's class that she did not check the homework herself and therefore did not know if it had been completed or if all students understood. During the observations, the only way she became aware of misunderstandings was when a student asked, and not all students asked when they had a question. (I noticed that several students who had made mistakes did not ask for clarification.)

After reviewing the homework, Cathy stated that she conducted a warm-up activity with the students. This very brief activity, according to Cathy, either "gives the students an idea of what they will be learning about today, or reinforces a concept that they learned the previous day." During my observations in the beginning of the year, both warm-up activities were review.

Next came the lesson, or as Cathy called it "the educating part." According to Cathy, this section lasted anywhere from 20 to 35 minutes and involved teaching the students a new concept by either giving them a note page to glue into their math notebooks or by having them take notes. During this time, Cathy was teaching while the students were listening. When Cathy was finished with the instruction, she usually had the students practice what they had learned. When talking about the structure of her lesson portion, she claimed that she "always tries to incorporate at least one hands-on approach in the lesson," but if she cannot there will be a "worksheet of some sort that is at least away from the textbook." During both observations, there were not any hands-on activities during the lessons and only one of the lessons included a worksheet of practice problems. However, this worksheet on percentages included word problems and scenarios that students would encounter in the real world.

Again from the two observations, while Cathy's lesson portion consisted mainly of students sitting and listening to her, she did incorporate discussion throughout and tried to clarify the relationship of what they were learning to the real world. For example, during a lesson on inequalities, Cathy asked the students to think of examples where an inequality could be used in the real world. The students struggled and failed to come up with an answer so Cathy suggested roller coaster height requirements: you have to be greater than or equal to a certain height to ride. In addition, when the students were doing practice problems, Cathy asked the students to explain how they solved each problem and then asked other students if they had used a different approach. By doing this, Cathy was exposing the students to various strategies for solving the same problem.

Lastly, during each of the beginning-of-the-year observations, I discovered that Cathy ended with some type of group game, although she had not mentioned this activity during the pre-interview. These games were both hands-on, which may have been her way of incorporating a hands-on activity. Both games reviewed concepts previously learned *and* activated the higher-level thinking skills of strategizing and looking for relationships.

Decision-making influences. When Cathy described her mathematics lesson planning and teaching, she mentioned what she believed influenced her decision making. The most important influence for her was the school district's pacing guide. This document lays out exactly what is to be taught in sixth grade, based on the Virginia Standards of Learning (SOLs) and when it should be taught during the year. Next, Cathy believed firmly in having some type of hands-on activity in each lesson, so after deciding what concept(s) would be taught on a particular day, she referred to sources other than the textbook to find such activities. Another important factor was the academic level of her students as a whole class. Cathy mentioned that one of her sixth-grade classes was not as strong in mathematics as the other. Specifically, they needed more time to process the concepts and had a very basic number sense. For these students, then, she always provided note pages for each lesson. In addition, Cathy spoke of the importance of showing students different strategies to solve problems beyond just the pencil-and-paper method and of the need to explain why they are learning each concept and how it could be useful to them. Cathy felt that by using these strategies, she was "able to accommodate the various learning styles in her classroom" as well as "provide purpose to

what they are learning in mathematics." In sum, Cathy's beliefs about teaching

mathematics (e.g., the incorporation of hands-on activities) and her knowledge about

student learning were influences on her decision-making processes, but as with Emma,

the SOLs were the most influential factor.

Incorporation of problem solving. During the pre-interview, Cathy discussed

how she incorporated problem solving into her mathematics classroom. She learned from

another teacher during her first year of teaching that it was best to first teach all of the

concepts and then include a problem-solving activity. This problem-solving activity,

according to Cathy, involved the students reading through a word problem and then using

the knowledge that they had just gained to solve it. She taught the four steps to problem

solving: understanding, planning, solving, and checking. Like Emma, Cathy found word

problems in the textbook where they were incorporated into each chapter a couple of

times. Cathy also mentioned a resource she used, *The Problem Solver 6* (Moretti,

Stephans, Goodnow, & Hoogeboom, 1987) which offered various higher-level word

problems where the students were to use newly learned strategies to solve each problem.

However, Cathy stated that she "has not had the opportunity to use it that much because

there is just too much curriculum to get through." In addition to giving the students word

problems occasionally, Cathy included word problems on homework assignments and

"definitely on their chapter tests," but these were textbook-generated.

Summary of beliefs, perceptions, and instructional practices. Like Emma,

Cathy had some beliefs about teaching and learning mathematics that parallel the reform

view of teaching mathematics. Such beliefs include incorporating hands-on activities so

students are actively engaged, teaching multiple strategies to solving a problem, and relating mathematics to real life (Bright & Vacc, 1994; Capraro, 2001; Chapman, 1999; Chauvot & Turner, 1995; Crespo, 2003; Ford, 1994; Gravemeijer, 1997; Millard, et al., 2002). I saw evidence of these beliefs when I observed her two observed mathematics lessons. However, the majority of her instructional style followed a more traditional approach: (a) relying heavily on the textbook for instruction; (b) providing students with note pages and/or notes which describe specific algorithms, formulas, processes, etc. for understanding a concept; (c) practicing previously learned concepts in a rote manner ; (d) emphasizing correctness of problems rather than process; (e) using a lecture-style lesson where she teaches and the students listen/take in the information; and (f) integrating problem solving a couple of times for each chapter solely via word problems from the textbook (Collier et al., 2002; Drake & Sherin (2006); Fennema et al., 1996; Fernandez (1997); Vacc & Bright, 1999; Vacc et al., 1998).

Incorporation of a Problem-Solving Based Professional Learning Community and Problem-Solving Lessons

The second phase of data collection included observations from all five of the PLC meetings as well as three observations of each participant implementing a problem-solving lesson in her mathematics classrooms. To more easily manage and analyze all of the data, I further divided the analysis for this phase into three sections. The first section included PLC meetings 1, 2, and 3 as well as one observation of each participant implementing the same problem-solving activity (October 15, 2007-January 7, 2008). Section 2 included PLC meeting 4 and an observation of each participant. However, for

this observation, each participant implemented a problem-solving activity of her own

choosing (January 16, 2008-February 11, 2008). Finally, the third section was comprised

of an observation of another problem-solving activity (again each participant chose her

own activity) as well as the last PLC meeting, meeting 5 (March 13, 2008-April 21,

2008). Table 3 provides an overview of all five PLC meetings.

Table 3

Summary of PLC Meetings

Meeting Date	Members	My Role	Outcome
PLC #1 10/15/2007	• Cathy • Emma • Fifth-grade teacher • Fourth-grade special education teacher • Myself	• Provided information about problem solving • Provided examples of problem-solving activities • Shared personal teaching experiences with problem solving • Guided discussions	• New data was gathered about problem-solving beliefs of Cathy and Emma • All members were ready to look at problem-solving activities next meeting and choose one to implement
PLC #2 11/19/2007	• Cathy • Emma • Fifth-grade teacher • Myself	• Provided examples of problem-solving activities • Provided *Students' Thinking Sheet* • Supported the development of a problem-solving activity • Guided discussions	• Choose and adapted a problem-solving activity to implement
PLC #3 01/7/2008	• Cathy • Emma • Fifth-grade teacher • Fourth-grade	• Provided structure for discussions • Shared my implementation and observations of the	• Each participant was going to choose and adapt her own problem-solving activity and then share implementation and

		activity • Added to participants' sharing based on my observations • Guided discussions	observations at next meeting
PLC #4 02/11/2008	• Cathy • Emma • Fifth-grade teacher • Myself	Same as PLC #3	Same as PLC #3
PLC #5 04/21/2008	• Cathy • Emma • Fifth-grade teacher • Myself	Same as PLC #4 Also shared how to create a useful resource for other teachers using the problem-solving activities that were implemented	• Decided that each participant would revise both problem-solving activities that she had implemented, thus creating a resource for other teachers. The format would be: (a) problem-solving activity, (b) teacher page, and (c) list of possible modifications and extensions

Section 1 (October–January)

This section of data analysis included data collected between October 15, 2007 and January 7, 2008, including observations and videotapes made during the first three PLC meetings as well as observational notes taken during each participant's implementation of the first problem-solving activity. Section 1 covered a longer period of time than the other two sections so as to include first two PLC meetings, which provided the participants with information they needed about problem-solving research, implementation of problem-solving activities, and examples of such activities. Armed with the background knowledge and the experience of creating a problem-solving

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activity, the participants were ready to implement this activity in their own classrooms

(first problem-solving observations). I concluded this section with one more PLC meeting

to allow the participants to discuss their implementation methods and observations during

the problem-solving activity. Each of the four parts, PLC meeting 1, PLC meeting 2, the

first problem-solving observations, and PLC meeting 3, is discussed below.

PLC Meeting 1. Based on the information that I collected during the pre-

interviews about their problem-solving knowledge, beliefs, and instructional practices, I

determined that both participants appeared to lack knowledge in and experience with the

current/reform views of problem solving. Therefore, I began PLC meeting 1 on October

15, 2007, by providing background information on problem-solving research, its

effectiveness on student achievement, and the reform views (versus the traditional views)

of how problem solving should be carried out in the classroom. In addition, I shared my

experiences with problem solving over the seven years of my teaching career. I

communicated this information to the group members via a PowerPoint presentation that

I had created. As my intention was to enhance the group members' knowledge of

problem solving, not change their way of teaching, I provided information that would add

to the knowledge they already possessed about problem solving in mathematics. I

concluded my presentation by giving the teachers examples of problem-solving activities.

I opened my presentation by discussing a journal article from *Teaching Children*

Mathematics that included a problem-solving activity titled "Height in Coins" (Ellis &

Yeh, 2007). This journal has a "Problem Solvers" section in each issue featuring a

problem-solving activity with commentary by the teachers who implemented the activity,

along with their observations of their students. I chose this article and activity because

(a) it was from the most recent journal, (b) I wanted to point out the difference between a

"word problem" and a problem-solving activity, and (c) I wanted to provide participants

with a resource for problem-solving activities. Participants looked through this problem-

solving activity and then shared their thoughts. It was during this sharing and thorough

discussion that I learned more about each participant's thoughts and beliefs about

problem solving.

The members present during PLC Meeting 1 were: Cathy, Emma, a fifth-grade

teacher, a fourth-grade special education teacher, and me. The fifth- and fourth-grade

teachers were not participants in this study; however, their contributions to the discussion

had an indirect effect on the participants and therefore I will mention their contributions

when relevant. During the meeting as observed on the videotape, Emma had some

questions regarding problem-solving activities, but seemed to understand the benefits.

These questions and understandings began to emerge after Emma scanned the various

problem-solving activities that I had provided. Emma wanted "the answer key." These

problem-solving activities were open-ended questions that required many steps and

processes to arrive at an answer. Further, parts of the activities could be interpreted in

more than one way, leading students to take different directions and, as a result, arrive at

different solutions, which all solve the problem equally well. There may not necessarily

be one single answer for an activity. Emma's question about an answer key illustrated her

focus on the correct answer rather than on the strategies the students would use and their

ability to explain and justify why a solution adequately answered the question/addressed the task.

Following Emma's question, as observed on the videotape, she stated that these problem-solving activities could be very time consuming, but "capture many best practices by engaging students, having them work in groups, helping them conceptually think about and apply mathematical concepts, and provide examples of how what they are learning in math class can relate to their lives outside of school." In addition, Emma liked how these problem-solving activities required various manipulatives for the students to work through a problem. Lastly, she commented that by having the students engage in problem-solving activities, students learn by teaching each other in groups, rather than listening to the teacher deliver the information. She noted, "The teacher takes on the role of a facilitator."

During this discussion about the problem-solving activities, while Cathy did not contribute as many thoughts as Emma (as noted from viewing the videotape), she too stated a benefit of such problem-solving activities. She mentioned after looking at the various problem-solving activities that they "don't necessarily need to be done at the end of a [mathematics] unit which they may relate to." Instead, she suggested that they could be used as "an introduction to a unit" so that students would be required to use their prior mathematical knowledge to construct their understanding of new mathematical concepts. Such a statement demonstrated that Cathy seemed to believe in the importance of students using their prior knowledge to expand their mathematical knowledge.

Following this discussion on problem-solving activities, I shared the book

Children Are Mathematical Problem Solvers (Sakshaug, et al., 2002) with the group. I

explained how this book provided 29 sample problem-solving activities. In addition, each

activity included guidance for teachers on how to implement these activities in their

classrooms across various grade levels. There were also examples of the strategies and

thought processes students had actually used at different grade levels while completing

the activity. This section demonstrated how many different strategies students could use

and how their solutions and thought processes differed. The different student strategies

sparked a discussion between Emma and Cathy, which provided more insight into their

beliefs about implementation of problem-solving activities as well as students' uses of

strategy.

As seen on the videotape, Emma began the discussion: "I like the idea of not

teaching one particular strategy to solve a problem and that sharing the different

strategies allows the students to see how one problem can be solved or thought about in

different ways." However, Emma continued by saying that she does "not think that it

would be [plausible] to start off in this way with the students because they may not even

have an idea about how to begin" due to their lack of known strategies. Cathy responded,

"I like problem-solving activities like these because of the open-endedness and that they

force the students to explain their thinking." She then added that when the teacher

provides students with a particular strategy to use, "The teacher is just giving them steps

to follow in order to solve the problem rather than allowing them to use their prior

mathematical knowledge and strategies." Most importantly, she continued by explaining

how she also liked these problem-solving activities because they were different from simple word problems (often only requiring one step to solve), which have set answers and generally only require one strategy to find a solution. Cathy ended by summarizing that these problem-solving activities are "more open-ended, focusing on discourse and [justification] of the solution" which she felt was important.

As noted from the videotape, Emma agreed with Cathy, but expressed her concern that students could get stuck in a rut, using the one strategy they knew for everything. Instead, she suggested that it might be better "to teach the students various strategies in the beginning and allow them time to practice using these strategies." Then, when they were presented with open-ended problem-solving activities, they would have many strategies to choose from and would not "get stuck, not knowing where to begin or how to proceed." I then gave Emma some examples from my classroom when students were not given strategies beforehand. I explained that when students shared after each solving the problem, it was apparent that they had used several different strategies. Clearly, they had been able to make sense of the problem, think of a strategy to use, and work out the problem. I concluded that this success demonstrated that the students were capable of thinking on their own, rather than being told exactly what to do to solve the problem.

As seen on the videotape, Cathy nodded and Emma responded with surprise, interest, and understanding. I concluded the meeting by providing the members with an article from the September 2007 journal issue of *Teaching Children Mathematics* called "To Share or Not to Share—*How* is the Question!" (Hagen, Hooyberg, Marsden, Simonski, & Yuen, 2007). This article described how five mathematics teachers from

different grade levels implemented the same problem-solving activity and their observations of their students. I summarized the main points of the article: (a) the same problem can be given to students of all grade levels with slight adaptations, (b) the mathematical knowledge the students possessed at the various grade levels influenced how they solved the problem, and (c) keeping the problem open-ended and not directing the students to any particular method to solve the problem calls on higher levels of student thinking and interpretation (Hagen et al., 2007). I wrapped up the meeting by suggesting that the members read the article if they had time because we would discuss the main points further at the next meeting. I also explained that next time we would look at various problem-solving activities and then choose one to implement in the classroom.

My discussions with Emma and Cathy document their exploration of problem-solving activities and their responses to and thinking about the new information provided to them about such activities. At this point in the year, based on data from the pre-interview and videotaped discussions from the first PLC meeting, Emma portrayed a more traditional view about problem-solving than Cathy; her focus was on the correct answer as well as teaching and practicing specific strategies first. The same data indicated that Cathy expressed beliefs associated with a reform view (allowing students to come up with their own strategy, focus on discourse and justification for their solution), and she also seemed to recognize differences between word problems and problem-solving activities.

PLC Meeting 2. The second meeting was held about a month later on November 19, 2007 with Cathy, Emma, the fifth-grade teacher, and myself present. The focus of this meeting was to look more critically at various problem-solving activities in order to agree upon and create an activity to implement in the classroom. During this process, many discussion points emerged that provided further insight into the participants' current and developing thoughts about such activities.

I began the meeting by providing each member with samples of problem-solving activities. Prior to the meeting I selected 11 activities from the book *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002) that I thought the teachers could use, based on the mathematics curriculum that the participants might be teaching and the feasibility of implementing the activity. I assembled a packet with these problems from the book and a copy of its introductory section explaining ideas and theories about problem solving and the role of the teacher during implementation. My intention was for the group members to see examples of the type of problem-solving activities that they could use; I left it up to the group whether they wanted to use an activity from the book or create their own. All members of the meeting took some time to peruse the packet and while doing so, all agreed that these were complex problems that involved many steps and higher order thinking skills. As seen on the videotape, Emma initiated the first and most discussed topic, implementation, when she said, "I know that we are trying to infuse [problem-solving activities] into the classroom, but I am just trying to think about ways to actually use them in the classroom."

Three ways of implementing problem-solving activities came out of the discussion: (a) distributing to students who finish early for extra credit, (b) completing in math class in groups, and (c) assigning for homework where the students discuss their strategies and solutions as a whole class the next day. The first was mentioned by Emma:

In my class, the students that finish early are always asking me what they can do while they wait…I [really] like these [problem-solving] activities and am thinking of making a little book with a bunch of problems for the students to complete.

Another member suggested doing the problem-solving activities in the classroom at the same time so that the students could work in heterogeneous groups based on mathematics ability to generate strategies, discuss their thinking, and arrive at a solution.

Finally, Cathy mentioned the third implementation model by explaining an activity she did while in a mathematics method class during graduate school:

When I was in [graduate] school, my instructor was really into problem solving. She would. . .give us a problem every week [to solve on our own at home] and then we would meet the next week. . . .These problems were not necessarily hard, but challenging enough where we would have to explain our thinking. During the class, [each person] would bring their solutions. . .and share how they solved the problem. . .I thought this was a very effective activity because everyone would be exposed to how many different strategies could be used to solve the same problem. . . .It helped me think about math in a different way.

All three implementation models were acceptable, but the differences between Emma's and Cathy's implementation models demonstrated a difference in their

understanding of the purpose and effectiveness of such problem-solving activities. Lastly, to end this discussion I acknowledged that all three implementation methods were plausible, but for the purposes of our PLC group, we would implement the problem-solving activities during class rather than as a homework assignment so that they could observe their students as they worked. Participants could choose how to present the activities and how the students would work (independently or in groups).

The last portion of the meeting was used to decide on a problem-solving activity that everyone would implement in the classroom (either an activity chosen from the book or one participants created from scratch). All of the members agreed that it would be easiest to choose an activity from the book, *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002). To simplify the process, I suggested some specific problem-solving activities that I thought might be appropriate. All members liked the problem "Decoration Delight," which deals with combinations, especially since it featured snowmen, given the season. After discussion and using the six design principles for creating model-eliciting activities as a guide (Lesh, et al., 2000), the group decided to change the wording of the problem to make it clearer for the students. In addition, two extension questions were added to differentiate for the students' various math ability levels. Finally, as noted on the videotape, Cathy suggested, to "add a part at the end to encourage [student] explanation by having them write a letter to the store owner. . .acting like a consultant." (See Appendix C for the final version of "Decoration Delight.")

During this process both Emma and Cathy contributed comments that helped illustrate more of their beliefs and thoughts about implementing problem-solving

activities in the classroom. Emma's comments and questions were largely related to

concerns with the implementation process. First, she said that she liked the last part of

the problem where the students needed to explain their thinking in a letter to the store

owner. However, Emma thought this activity would be difficult for her students because

"a lot of my students can get the correct answer; but when they have to … explain how

they got the answer, they can't do it." Next Emma asked a series of questions:

> Are we going to be doing this in groups? Also, I do not see an answer; are we
>
> going to give [the students] the correct answer? Are we going to teach first before
>
> giving the problem [solving activity] so that they know what to do?

Clearly, at this point Emma was still concerned about the students arriving at the correct

answer as well as feeling the need to provide a starting point or an indication of what to

do.

> Cathy's comments and questions were quite different from Emma's as seen on the

videotape and focused on the students' strategies:

> I think it [is going to] be interesting to see the dominant answer or the dominant
>
> method for each grade level and how it might vary from one grade level to the
>
> next. Will there be a progression in strategies as they move up grade levels? What
>
> changes?

Cathy seemed to be interested in the students' strategies, processes, and thinking while

solving the problem-solving activities. She also seemed curious about how these

strategies might differ and develop across the different grade levels.

At the end of the meeting and because the focus of the third PLC meeting was going to involve discussions about implementation and students' thinking, processes, and strategies during the activity, I provided everyone with a graphic organizer, called a "Student Thinking Sheet," that could be used to record these data. (See Appendix D for this graphic organizer.)

In summary, during the second PLC meeting, Emma again expressed more traditional views of problem solving (still focused on the correct answer, feeling the need to provide guidance to the students, and showing apprehension about the students' abilities). Her concerns and questions about implementing the problem-solving activity might have been signs of her inexperience with such activities. However, she seemed to be looking forward to implementing the activity. On the other hand, Cathy's comments and questions throughout the meeting were indicative of familiarity and experience with problem-solving activities. She did not appear to be worried about the implementation and instead was looking forward to analyzing and discussing the students' strategies and processes within and across the different grade levels.

First problem-solving observations. Emma implemented "Decoration Delight" on December 4, 2007 and Cathy on December 7, 2007. Both allotted the entire one-hour class to the students, working in groups of three or four, to solve the problem. During my observations of both participants, I found some similarities in their implementation, but more differences.

Emma's class. On the day of implementation and observation, Emma had 22 sixth-graders who have been learning sixth-grade math all year. Emma introduced the

problem by explaining to the students that they would be completing a problem-solving

activity without much direction from her. Their final product was to be one letter, written

in proper letter-writing format, from each group to the store owner. Before the students

broke into groups, Emma read through the entire problem with the students and had them

highlight the "big question." The students then got to work.

I observed that Emma walked around to each group while they worked on the

problem. Emma provided advice in response to student questions, and on multiple

occasions while they were working on the first portion of the activity—four parts and

four colors—made recommendations on how to solve a portion of the problem without

supplying the answer. Further, she stopped the students a couple of times when she

observed common misunderstandings/questions and discussed the issue with the entire

class. For example, many students thought that the four parts and four colors would only

yield four different snowmen. Emma explained that the colors could be used in different

orders.

The students worked for approximately forty-five minutes using various strategies

to find a solution for all three questions (four, five, and six colors). During this time, I sat

in the back of the room and took notes on the strategies and materials the students used,

the small group discussions, student questions, and student explanations. I also took notes

when the whole class interacted with the teacher, and I walked around to the various

groups, taking notes when the students worked in groups. Based on my observations and

notes students used three main strategies: (a) drawing a picture of a snowman and

coloring the different parts, (b) using highlighters of various colors to make the

combinations, and (c) making a list using abbreviations they had devised for each color. Some of the groups who used the listing strategy struggled to keep track of the combinations because their listing was not logical or sequential, resulting in omission or repetition of some combinations.

Although in groups, most students worked on their own or with a partner within that group rather than in a group as a whole with shared discussions. As Emma had anticipated, the students were concerned about the correct answer. Towards the very end of the class, Emma gave the correct answers to the students and reminded them to complete the letters. By giving the students the answers prior to the letter writing, Emma's emphasis appeared to be on correct answers rather than on the students' strategy use and thinking processes and reasoning.

Although the students tended to work on their own within the group, each group produced one letter. As the class drew to a close, the students rushed to finish and hand in their letters; there was no time for a discussion on strategies and processes. In the end, out of the seven groups only one completed all three parts of the activity (four, five, and six colors). The other six groups completed the task for four and five colors, but did not even start working on six colors. All of the groups ended up discovering the correct number of combinations for four colors, only one group found the solution for five colors, and no group was able to come up with a solution for six colors.

Cathy's class. On the day of implementation and observation, Cathy's class consisted of twenty-four sixth graders who had been learning seventh-grade math all year. Cathy began the activity as had Emma; she read through the problem with the

students to ensure that they understood their task. However, in addition to going over the task, Cathy stressed the importance of explaining the thinking and processes they used to work through the problem in their group letter. Cathy addressed several questions students asked prior to getting started. Cathy also offered the students scrap paper, colored pencils, and Unifix Cubes. Before sending the students to their groups, Cathy reiterated that this was a multi-step problem where they would first do the math to come up with a solution and then write a letter to explain the mathematics and the strategies used.

While the students worked in their groups, Cathy walked around and asked the students to explain to her what they were doing and what they were thinking. She did not advise them in any way; she simply listened to their explanations and gave them feedback in the form of compliments or questions to consider as they developed their strategies. Cathy jotted down all of the different strategies that she saw her students using.

Again, I took observational notes while the students worked and walked around to each group taking notes. In Cathy's class students used five different strategies: (a) drawing a picture of the snowman and coloring each part (same as Emma's students); (b) making a list using abbreviations for each color (same as Emma's students); (c) using Unifix Cubes of different colors to "build" the different snowmen; (d) finding patterns across colors (e.g., for the first part—four colors and four parts—students discovered that when one color was used for the head, there were six different snowmen possibilities and, therefore, each of the other three colors, when used for the head, would yield the same number of combinations, resulting in 4 colors x 6 combinations = 24 different snowmen);

and (e) creating a tree diagram. Cathy's students appeared to use more advanced thinking strategies than Emma's and the groups that used the "making a list" strategy were logical in their approach and thus able to keep track of all of the combinations. Of course, the ability Cathy's students demonstrated to employ more effective strategies and see patterns was not necessarily due to a superior lesson; because these students were learning seventh-grade math in sixth grade, they might have been more mathematically advanced than Emma's

Additionally, Cathy's students appeared to work more collaboratively in their groups than Emma's students. In each of my two observations of Cathy's teaching earlier in the year, she had an activity during the hour period where the students worked in groups. Perhaps Cathy's students worked more collaboratively in groups during the problem-solving activity because of their prior experience with group work. At the very beginning of the activity, Cathy's students each made sense of the task individually and tried their own strategies. However, very soon afterwards the students moved towards discussion with one another. The students as a group discussed their findings and strategies for the first part involving four colors. After that discussion, again as a group, they used one of the strategies they had discussed to solve the next two parts (five and six colors) together. More discussion appeared to take place after Cathy had visited each group and asked questions. In essence, she encouraged discussion among the group members.

As noted in the observation, Cathy's students were very involved in this problem and worked through all three questions for approximately forty-five minutes of class, but

still needed more time. As a result, only one group wrote their letter by the end of class.

Cathy had gathered so much information about the different strategies used that she said

she was not concerned about the letter. However, to conclude the activity and in lieu of

the letter, she spent the first half of the next day's lesson allowing the students to share

their strategies with the entire class. In the end, all six of Cathy's groups completed all

three parts. Cathy was less concerned about the students arriving at the correct amount of

combinations than probing the strategy used and the explanation of student thinking

throughout the process.   All six of Cathy's groups discovered the correct number of

combinations for four colors and five colors, and four groups found the correct answer

for six colors.

   Summary of and comparison between both classes. In summary, Table 4

displays similarities and differences between Emma's and Cathy's implementation of the

problem-solving activity, "Decoration Delight," as well as the students' strategies and

successes.

   These observations provided documentation on how each participant

implemented problem solving in the classroom and how students responded to such

activities. Emma seemed more focused than Cathy on the students coming up with a

final product. In addition, due to her concern over students' questions or lack of certainty

on what to do, she provided assistance quickly at the beginning of the activity. Finally,

she did not provide any conclusion to or wrap up the activity; instead, she summarized

the activity and provided the correct answers for each part. As a result, there was very

little discussion at the end of the activity. On the other hand, Cathy seemed primarily

interested in the students' strategies and thinking as they worked towards their solutions.

Further, she offered very little assistance to the students, allowing them to think through,

make sense of, and come up with a strategy on their own. Lastly, Cathy did provide a

conclusion to the activity the next day (whole-class discussion of thinking processes and

strategies).

Table 4

Similarities and Differences During Implementation of "Decoration Delight"

Characteristic	Emma	Cathy
Introduction of Problem-Solving Activity	• Ensured the students understood the "big question" • Focused on writing the letter	• Ensured the students understand the task • Focused on their thinking processes and strategies
Materials Provided	• None	• Unifix Cubes • Colored pencils • Scrap paper
Assistance Throughout Activity	• Provided ways to solve the problem and/or strategies to use • Explanation to whole group of misunderstandings	• Asked students questions about their thinking/strategies • Guided students to discuss amongst themselves
Student Group Work	• Worked individually or with a partner • No discussion	• Started off working independently • Discussed strategy for part one (four colors) • Worked as a group to complete parts two and three (five and six colors)
Student Strategies Used	• Three strategies (drawing a snowman, using a highlighter, and making a list)	• Five strategies (drawing a snowman, making a list, using Unifix Cubes, finding patterns across colors, and creating a tree diagram)
Accuracy of Students' Solutions	• All seven groups arrived at the correct number of combinations for four colors	• All six groups arrived at the correct number of combinations for four and five colors

	• Only one group got all combinations for five colors • No groups attempted six colors	• Four groups got all combinations for six colors
Conclusion/ Wrap-Up of Activity	• Students handed in letters • Teacher gave correct answers	• Whole-class discussion of thinking processes and strategies the next day

PLC Meeting 3. The third meeting was held on January 7, 2008 after all members had implemented the problem-solving activity, "Decoration Delight," into their classrooms. The purpose of this meeting was for all members to discuss how they had implemented the activity and share their observations of the students' thinking processes, strategies, and solutions. Emma, Cathy, the fifth-grade teacher, the fourth-grade special education teacher, and I were present. Most of the two-hour meeting was devoted to each of the five members sharing her implementation and observations, rather than to group discussion.

I started the meeting by explaining how everyone should share their implementation of the problem-solving activity. The group decided that we should start with the lower grades and work our way up to the higher grades. Therefore, the fourth-grade special education teacher started. As noted in the videotape, she only had four students so she did the activity with the whole group, providing the students with big, blank snowmen to color four colors of markers. They started the first one together and then began working independently to "create" their many snowmen. The students got very creative, coloring one single part of the snowman, for example the head, two different colors.

This presentation sparked a discussion in our group about the different ways the students found to use the colors and questions that arose while the students were coloring. Students' questions were: (a) Could the same color be repeated on a snowman? (b) Could one part of the snowman be split into different-colored sections? and (c) Could one part, say the head, be constant while the other three parts changed colors? The members discussed how the thinking of these students could lead to many different solutions for the same question. We decided that since students across several grade levels had similar thoughts, it would be useful to discuss these questions in the introduction to this activity, yet ensure that the students understood that: (a) no color can be repeated, (b) no section can be divided, and (c) one part can remain the same color while the other parts change. Cathy noted that it was important for the students to all have the same criteria from the outset or else they would not be solving the same problem. In addition, she commented, and the group agreed, that if they allowed the students to repeat colors and split a part into sections, the number of combinations would be infinite, rendering a solution impossible.

After the fourth-grade teacher finished sharing, as seen on the videotape, Emma commented that she liked the idea of using the big snowman as an introduction. She then suggested to the other teacher that since the students had taken so long to color the snowmen that the lesson was to be continued the next day, she might consider using smaller snowmen and clarifying that each section could be one color only and no color could be used more than once on a snowman. The fifth-grade teacher shared a sheet of 36 small, uncolored snowmen she had given her students. She suggested that the fourth-

grade teacher distribute the sheet and advise her students to start with one color for the head; from there they could see how many different combinations the students could make with that head color. The fourth-grade teacher agreed with these suggestions, and Emma liked the idea of providing the students with the sheet of snowmen as a tool for solving the problem.

Next, the fifth-grade teacher shared her experience with the problem, which included the idea of teaching the students how to make tree diagrams prior to the activity. She also went through an example, relevant to the activity, with the students about the different possible orders for three scoops of ice cream on a cone.

Emma then shared her experiences, followed by a reflection:

After listening to everyone share so far, I feel that I helped my students more in solving the problem than other teachers. I wonder what my students would have done if I let them on their own more, helping only when questions came up. [Also,] none of my students used a tree diagram. . .they used mostly a form of coloring the snowmen or making an abbreviated list. [However,] I noticed some groups looking for patterns and some students starting to discuss what they were thinking to other group members. . .I did not have enough time at the end to have a discussion with the entire class. . .which I now feel would have been a good way to wrap up the activity. . . .I was very pleased with how my students did overall.

Emma's reflection clearly indicated that she had listened to the other members share, had been struck by some of what they did in their classrooms, and then had thought about how she could improve her implementation.

Finally, Cathy shared, mentioning things that she did differently from the other teachers and unique observations of her students. She explained how she "was very hands off as far as guiding them" and said, "If the students came up with an answer and asked me if it was correct [and it wasn't], I told them that they were close, but should look at it again." In addition, Cathy commented about her students' strategies:

I feel that the major difference between my students and everyone else's were the strategies that they used. They were amazing strategies, very different than any other strategy mentioned. It did take many of my students a little while to determine which strategy worked best for them. . .and to see patterns across colors, but eventually they all did and every single student got the solution for four and five colors and about half if not more of the class got the solution for six colors. . . .Since they used complicated strategies, it was often difficult for the students to explain their strategy to others so they could understand what they did. [However, what] I noticed was that many of the strategies or patterns that they used/saw were the conceptual thinking behind the permutation formula and using factorials.

As noted in the videotape, while Emma reflected primarily on what to change next time and a little on the students' strategies, Cathy focused heavily on the students' strategies and did not mention anything about improving her implementation. As noted earlier, Cathy's students were learning a higher level of math (seventh-grade math) than any other class. Understanding permutations and combinations and learning the relevant formulas is part of the seventh-grade curriculum; therefore the students might have been

developmentally ready to understand these concepts. However, they had not been taught them yet.

To end the meeting, I summarized the group's observations: (a) There is a continuum between grade levels in student thinking, strategies, etc. (b) Students have difficulty explaining their thinking, processes, and strategies. (c) Teachers differed in how much guidance they provided and what materials they offered. And, (d) the students exceeded many of the teachers' expectations for solving this problem-solving activity. The group decided to implement another problem-solving activity, but this time one of their choosing from the book *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002).

The sharing, discussion, and reflection provided further insight about each participant. Emma seemed willing to listen to the different ways each teacher implemented the problem-solving activity and to look critically at her own implementation, finding ways to improve it for the next time. Cathy, on the other hand, appeared confident in her implementation and focused mainly on her own students' strategies and thinking.

Section 2 (January–February)

This section of data analysis included data collected from January 16, 2008 to February 11, 2008. Data included in this section were observational notes from the second problem-solving activity implemented by each participant as well as the observations from and videotaping of the fourth PLC meeting. Section 2 of the data analysis spanned a shorter period of time than Section 1 because I felt that the two parts

(second problem-solving activity and PLC meeting 4), complemented each other. Both

are discussed below.

Second problem-solving observations. Following the third PLC meeting, each

participant chose her own problem-solving activity to implement from the book *Children*

Are Mathematical Problem Solvers (Sakshaug, et al., 2002). I observed Emma on January

17, 2008 and Cathy on January 24, 2008.

Emma's class. Emma chose the problem "What Shapes Can You Make?" (See

Appendix E for a copy of this problem.). In this problem-solving activity, students were

asked to place four isosceles triangles together along their edges without allowing them

to overlap to make as many different shapes as possible. As observed, Emma began the

lesson by introducing the students to the tangram (a manipulative available in different

shapes) by taping four tangram isosceles triangles to the board. Next, Emma distributed a

write-up of the problem to be solved, which the class read together. Emma then drew two

shapes on the board. She asked if the two shapes were the same. Some students said yes;

others said no. Emma explained that they were in fact the same shape, because they were

congruent, just rotated differently. She then discussed the terms *congruency*, *reflection*,

rotation, and *translation*.

"What Shapes Can You Make" was a problem-solving activity involving

geometric concepts. As Emma's students had not yet studied the sixth-grade geometry

unit, she briefly discussed a few concepts needed to complete the activity. By doing so,

she appeared to anticipate issues and questions that might arise during the activity. She

did not take this approach this during the first problem-solving activity; she addressed

misconceptions as they came up and answered students' questions directly. In her introduction to the second problem-solving activity she gave the students something to think about while solving the problem and provided some background mathematical knowledge. She concluded the introduction by explaining that the task involved trying to make as many "different" shapes as they could. Her earlier sketches on the board clarified that two congruent shapes flipped in different directions did not qualify as different.

In this activity, Emma asked the students to work with a partner rather than in groups of four or five students as they had done for "Decoration Delight." Each student chose a partner, gathered the necessary tangrams, and quickly got to work.

While the students worked, Emma walked around to the pairs. She observed the students and cleared up any misconceptions and answered questions. Many students asked if they could connect the shapes at a vertex. Emma directed the students back to the question, which required that triangles be connected by their edges and ensured that all students understood. She continued to circulate, providing the students with guidance as needed and asking questions about their shapes. For the most part, all pairs worked in a similar fashion: one student made the shapes with the tangrams and the other student drew a picture of the shape to record it. Discussions between the partners were frequent, generally centered on deciding if the shape was different from one previously made. Many students started naming their shapes, based on resemblances to familiar figures, for example, a rocket ship, a cat, Tennessee, and North Carolina.

With about ten minutes remaining, Emma had the students finish up, put the tangrams away, and prepare to discuss as a class the shapes they had discovered. Emma asked each pair to share one of their shapes using a round-robin sharing strategy: each pair, in turn, drew one of their shapes on the board, making sure each time that the new shape was different from those already displayed. This process continued until there were no more new shapes left to share. During this process, several discussions arose: (a) was the new shape "different"; (b) what name, if any, had the students given to their shapes; and (c) what geometric figures were formed by the four triangles, e.g., parallelogram, trapezoid, rectangle, etc. After all the shapes were shared, Emma ended the class.

It is apparent through this observation that Emma employed some of the instructional practices that she reflected upon during the third PLC meeting. First, she began with a brief introduction about the problem-solving activity to help the students fully understand the task. Emma appeared to have anticipated the issues that might arise (e.g., congruency), so she addressed them upfront with the class. Second, unlike the first problem-solving activity, where no manipulatives were made available, Emma provided the students with tangrams to use if they so desired. Third, while the students were working, Emma walked around and observed, provided guidance when needed, and asked questions. This approach differed significantly from that observed during the first problem-solving activity, where she frequently advised the students on what to do. Lastly, unlike the first problem-solving activity, Emma had a wrap-up activity: the brief group discussion of the students' solutions.

As observed, Emma introduced the two problem-solving activities ("Decoration Delight" and "What Shapes Can You Make?") similarly. However the implementations of the two activities differed in several ways; the second was characterized by: (a) availability of a manipulative, tangrams, if students were interested; (b) Emma offering guidance, not advice when needed; (c) introduction of key words (e.g., congruency, translations, etc.); and (d) wrap-up with a whole class discussion. Further, Emma was not as focused on the existence of "the correct" answer or on the students finding it. Instead, the students discussed their creations. It was not until the very end of class that the number of possible different shapes was revealed.

Cathy's class. For her problem-solving activity, Cathy chose "Counting Squares." (See Appendix F for this activity.) In this activity, the students were shown a four-row stair-step triangle made of congruent squares, starting with one on top and then increasing by two in each descending row. The students were asked to count how many squares there were. Then they were to add another row and count the squares and then continue adding rows and counting squares. Finally, they were asked if they could find any patterns that described how the number of squares was growing.

As an introduction, Cathy distributed the paper with the activity on it and told the students to take out their graph paper. She then read through the activity with the whole class and provided them with minimal additional information. She told them, "your group can decide how to interpret the question and where to go with it. . .and I hope that the words 'square' and 'pattern' stand out for you." The students then began to work in groups that were almost identical to those for the "Decoration Delight" activity.

Surprisingly, all six groups interpreted the word "square" in the same way: any square that can be formed in the stair-step triangle, meaning squares can vary in size—1 by 1 squares, 2 by 2 squares, 3 by 3 squares, etc. Cathy circulated while the students were working and asked what answers they were getting, how they were keeping track of counting the squares, and if they were seeing any patterns. One group realized that there were 18 more squares in the five-row stair-step triangle than in the four-row stair-step triangle. They then hypothesized that the six-row stair-step triangle would have yet again 18 more. Their hypothesis was proven incorrect when they counted all the squares. Cathy suggested that, rather than looking at the total number of squares, they should look for patterns in how the total number of a particular type of square changed (i.e., total number of 1 by 1 squares in the four-row stair-step triangle compared to total number of 1 by 1 squares in the five-row stair-step triangle). When the students discovered that in the four-row figure there were 16 1 by 1 squares, in the five-row figure there were 25, in the six-row figure there were 36, etc., they realized that the totals were perfect squares. They then applied their finding to the seven-row stair-step triangle and figured out that there would be forty-nine 1 by 1 squares in total. Cathy continued to walk around and suggested to the other groups where to look for patterns.

Lastly, as noted in the observation, Cathy brought the class together to discuss their findings. A representative from each group explained their solutions and patterns in the front of the class; many also drew their findings on the board. Class ended after Cathy had asked if any other students had something else to share.

This implementation was quite similar to Cathy's implementation of the first problem-solving activity: (a) There was an introduction and suggested materials (e.g., graph paper). (b) Very little information was provided about the activity, giving the students freedom of interpretation. (c) Key words were identified (e.g., "square" and "pattern"). (d) Guidance was provided to groups when needed. And, (e) a whole class discussion concluded the activity. Despite the similarities, the sharing at the end of the second activity did not promote as much discussion amongst the students as the first.

Summary of and comparison between both classes. In summary, it appeared that Emma had changed her way of implementing a problem-solving activity in several ways. She included in her introduction an explanation of an issue that might arise, provided the students with a manipulative to use if desired, assumed more of a hands-off role while the students worked, provided assistance when needed and inquired about the students' thinking, and wrapped up the activity with a whole group sharing and discussion. Perhaps these changes were linked to PLC meeting two, where Emma learned how other teachers implemented the same problem-solving activity in different ways, and she determined to approach the activity differently. Additionally, almost all of the changes she made were ideas that Emma had reflected upon during the meeting. In contrast, Cathy implemented the second problem-solving activity in much the same way as the first. Both Emma and Cathy chose problem-solving activities that dealt in some way with geometric concepts, specifically around shapes: making shapes from four isosceles triangles and counting squares.

PLC Meeting 4. Based on the effectiveness of the sharing and discussion session during the third PLC meeting, I decided to keep the same format for the fourth meeting. Emma, Cathy, the fifth-grade teacher, and I were present. Each member shared her chosen problem-solving activity, how she implemented it, and her observations regarding the students' thinking processes and strategies. Once more, the two-hour meeting was primarily spent on each teacher's sharing, with a small amount of discussion sprinkled throughout. These discussions are described here as they document Emma's and Cathy's continued exploration of problem-solving activities and responses to and thinking about new information about such activities. Lastly, while the other teacher did not participate in the study, I include her relevant contributions here as they had an indirect effect on the participants.

I began the session by sharing the problem-solving activity that I had implemented with my own students. The students were to figure out how many different ways a 2 x 3 unit cake could be cut into two equal parts. My students asked whether they could cut the cake into more than two pieces but still be able to give exactly the same amount to two people (i.e., one half of the cake might be one whole piece, while the other half might consist of two pieces). The fifth-grade teacher commented that that interpretation would lead to an infinite number of answers. Emma responded that "while there would be many solutions, the student's question displayed how they creatively thought about and interpreted the task at hand. . .and there might not always be one solution in a problem-solving activity so focusing on the students' strategies was more important." Emma's comment clearly reflects the evolution in her thinking. In the first

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PLC meeting, Emma had focused on the correct answer. In this meeting, her comment demonstrated the shift in her thinking from the correct answer to the student's interpretations, thinking, and strategies.

Next, Emma shared. She observed that she had taken on more of a facilitator role this time. Her comment on the closing discussion in her class pointed to another key element of her new implementation: "I noticed that by doing the group discussion in the end, the students fed off of one another and [therefore] I could sit back and mediate the discussion that was occurring amongst the students." Emma clearly was aware that she had made these changes and appeared to be happy with the results.

The fifth-grade teacher then shared her implementation; coincidentally she had used the same problem-solving activity as Emma. Therefore, in her sharing she simply discussed the differences and similarities between her implementation and observations and those of Emma. There were two similarities: (a) The students asked if they could connect the triangles by a vertex. And, (b) the students named the shapes after familiar images that they resembled. There were also two differences. First, instead of tangrams, the fifth-grade teacher gave each of the students sheets of grid paper with mini triangles traced on them, which they could cut out and manipulate. Further, they glued their shapes onto a large piece of construction paper, rather than drawing them like Emma's students did. Emma commented that she liked this idea better than using tangrams because she noticed that many of her students had had a hard time replicating the tangram shapes with pencil and paper. Second, the fifth-grade teacher did not do a mini-lesson on congruency and transformations like Emma did. Emma asked her, "Did the issue of congruency ever

come up while the students were working?" The fifth-grade teacher said it did come up in some of the groups after they had started working and had produced congruent shapes. In those cases she would ask the students in the group if those shapes were truly different. Emma again expressed her satisfaction with this idea and commented, "I guess you can give the students very little information and guidance in the beginning and can then address issues as they come up." Emma once again demonstrated her ability to reflect on her own instructional practices.

Lastly, at the conclusion of the fifth-grade teacher's sharing a point arose about the number of geometric concepts this activity addressed. We came up with: congruency; transformations; naming shapes such as parallelogram, trapezoid, etc.; measuring; perimeter; and area. Emma noted that this activity could be used as an introduction to the geometry unit. She also commented, "I could see doing this activity one day and then the next day discussing all the geometric concepts or referring back to this activity as the geometry concepts are taught." Here Emma had realized how problem-solving activities could be embedded within the mathematics curriculum.

Finally, Cathy shared the implementation of her problem-solving activity. Cathy made one interesting observation which sparked a brief discussion. She commented, "My students worked very well in groups and tried hard to find patterns but not many of them were successful. . .however, there was a limited amount of time." Emma suggested that perhaps she could extend the activity to the next day; she could start by re-visiting the patterns that had already been discovered and then have the students look for more, Cathy appeared to like that idea.

Overall, based on the problem-solving observations and the discussions from the fourth PLC meeting, Emma seemed to be changing her instructional practices as well as her beliefs about problem-solving. She had shifted to taking on more of a facilitating/guiding role during the activity and was beginning to ask the students to discuss their findings at the end of the lesson. Additionally, Emma was seeking various manipulatives/materials that she could provide to the students as well as considering how the problem-solving activity could be integrated into the curriculum. Cathy, however, did not appear to change during this session. It should be noted that she was already using some of the target instructional practices that Emma added to her implementation in the second activity.

Section 3 (March-April)

The third section of data analysis spanned from March 13, 2008 to April 21, 2008. The forms of data collected were exactly the same as those for section two: observational notes taken during the third implementation of a problem-solving activity and the videotaping of the fifth and final PLC meeting. Both are described below.

Third problem-solving observations. Following the fourth PLC meeting, each participant again chose a problem-solving activity to implement. Cathy chose another activity from the book *Children Are Mathematical Problem Solvers* (Sakshaug, et al., 2002). However, Emma chose an activity from a different book, *50 Problem-Solving Lessons: The Best from 10 Years of Math Solutions Newsletters* (Burns, 2004). I observed Emma on April 2, 2008 and Cathy on March 13, 2008.

Emma's class. Emma chose "The Budgie Problem" as her activity. (See

Appendix G.) In this activity, a bird collector wanted to buy 100 budgies with exactly

$100 and to receive at least one of each kind. Blue budgies cost $10, green cost $3, and

yellow cost $0.50. The students were to figure out how many of each color the bird

collector could buy. Emma added an extension where the students were to try and find

an algebraic solution. To introduce the activity, Emma simply read the problem to the

students and explained that a budgie is a bird. She then sent the students off to work in

groups of three or four students based on their normal table groups.

As noted in the observation, the students got right to work. Some groups worked

all together while the members of other groups worked more independently. Emma

visited each group and asked the students about what they were doing, what strategy they

were using, and what their thinking was. She asked probing questions of the students,

such as "Why are you using that strategy?" and "What is your next step going to be?"

The students basically all used a guess-and-check method, creating diagrams, tables, or

pictures to do so. The students continued manipulating the numbers as they got closer and

closer to having exactly 100 birds worth exactly $100. When it got close to the end of

the period, Emma explained to the students that she wanted them to wrap up and provide

her with their "closest" guess (their solution where the number of birds was the closest to

100 and the amount of money was the closest to $100). The students circled their

"closest" guess and handed them to Emma. Finally, Emma brought all the students

together and she asked the one group that with the correct solutions to share.

During this activity it appeared from the observation, that Emma was still trying new instructional practices during implementation. Her introduction was very short and included only a description of the activity and of the student's task. She did not teach a mini-lesson beforehand as with the second problem-solving activity. In addition, while walking around to each group, she asked probing questions in an effort to understand the students' thinking processes and strategies. In effect, Emma did not provide any assistance. Further, she appeared to be more focused on their processes while solving the activity than on their answers. By asking the students to hand in their "closest" guess, Emma made the students aware that she wanted to see what they had come up with and was not expecting a correct solution. Lastly, Emma did bring the class back together at the end but there was little discussion, just one group sharing the correct solution.

Cathy's class. Cathy chose the activity "Marbles," but renamed it "Which Box." (See Appendix H). In this activity the students were told that Sheryl had three labeled boxes containing marbles, as follows: (a) two blue marbles, (b) two red marbles, and (c) one red and one blue marble. Sheryl's sister, Angelica, decided to switch the labels around. Sheryl wanted to put the correct labels back on the boxes without opening them. The question the students were to tackle was: If Sheryl takes one marble from one box, can she determine the correct labels for all three boxes? Cathy introduced this activity by reading it to the class and pointing out that there was more to the answer than just "yes" or "no." Students would need to explain their answer.

As noted in the observation, the students got to work and, initially, questioned the "realness" of this activity: "Why doesn't Sheryl just open the boxes?" and "Why did her

sister switch around the labels in the first place?" Cathy handled this by explaining that, "Those are valid questions, but this is a challenge activity and sometimes questions are posed that may not seem realistic." Next, the students questioned whether Sheryl could pull one marble from each box or just one box. After Cathy had the class reread the problem, the students decided she could only extract one marble total. The students still thought the task was impossible. Therefore, Cathy gave them one pointer: all the labels were incorrect so automatically the students can eliminate that label as being correct for that box. After this explanation, the students realized the task could be performed and worked on proving it.

Cathy allowed the students to work for about 20 more minutes. Then, she pulled the class together to discuss their thinking, strategies, and solutions/justifications. Several students took turns coming up to the board to explain and draw their justifications. After the sharing was completed, Cathy posed an extension: "Could you do this if there were three different colored marbles and the same scenario, say the colors red, blue, and green? Let's say four boxes: (a) three red marbles; (b) three blue marbles; (c) three green marbles; and (d) one red, one blue, and one green." As a class they chose the strategy one student shared, using a logic grid; by establishing the grid, the students discovered that this task was impossible. To conclude the class, Cathy asked, "What mathematical concepts are you relying on to solve this problem?" As a class, the students came up with four: guess and check, process of elimination, reasoning, and logical thinking.

This activity and the way the students responded to the task caused Cathy to take a different approach in implementation. She began by providing the students with very

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little information, as she did during the other two problem-solving activities, but as questions arose she addressed them as a whole class. Additionally, since the students all thought the task was impossible, Cathy gave them a clue (reminding them of the incorrect labels and leading them to realize one label could be eliminated right away). Further, Cathy had the students work on this activity for about two-thirds of the class period. The last third of the class was devoted to sharing and discussing. In addition, Cathy posed an extension that the students worked through together, and she concluded the activity by having the students link this "unrealistic" problem with mathematical concepts. These last two actions were not part of Cathy's first two implementations.

Summary of and comparison between both classes. In summary, both Emma and Cathy appeared to make some changes in their instructional practices during implementation of the third problem-solving activity. Compared to the first and second problem-solving activity, in the third activity Emma provided less information in the introduction, offered little assistance during group work and instead asked probing questions, and focused more on the students' processes and strategies rather than on a correct answer. Cathy needed to provide some additional assistance and clarification to the students for them to come up with a solution, posed an extension question to the whole class, and had the students connect this activity with the mathematical concepts needed to solve it. These three actions were not part of the first and second problem-solving activities.

PLC Meeting 5. The final PLC meeting was on April 21, 2008. Again, every member shared the third problem-solving activity that they had implemented. Present

were Emma, Cathy, the fifth-grade teacher, and myself. The fifth-grade teacher shared

first and then I followed suit. A discussion occurred after our sharing because both of our

problems involved algebra or could have been solved by creating an algebraic equation.

However, the students found other strategies to solve both. In her discussion with the

class at the end of the activity, the fifth-grade teacher showed the class how an algebraic

equation could have been written. Then, the students went back to the activity and wrote

their own. As noted in the videotape, Emma was very interested in the fifth-grade

teacher's process, noting that she felt that she could use the same problem-solving

activity in her classroom.

> I would like to use this activity prior to teaching the students how to write and
>
> solve algebraic equations. . .it would be interesting to see if the students come up
>
> with one on their own. Depending upon if they do, the discussion at the end could
>
> lead into writing algebraic equations. If not then the activity could be re-visited
>
> [when learning how to do so].

Cathy agreed with Emma and commented:

> In the beginning of the year when [the students] worked on "Decoration Delight"
>
> they solved that problem using various strategies when they could have just used
>
> the formula for [calculating the number of] permutations. However, they had not
>
> been taught that formula yet. . . .Just recently I taught the students about
>
> permutations and combinations and their formulas. I referred back to "Decoration
>
> Delight" and re-visited it using the [permutation] formula. I thought this was a
>
> great connection to have the students make.

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Following that discussion, Emma shared her problem-solving activity. She pointed out that she had observed the students struggling a little at the outset, but that they had continued to work. Further, she let them work without providing assistance and she noticed the students "were able to find strategies, make connections, use logical thinking to figure out what type of budgie you would have less or more of, and discover substitutions" (e.g., six yellow budgies, $0.50 each, would be the same as one green budgie, $3 each). Finally, Emma added that only one of the groups came up with the correct solution, but many other groups were close. She predicted that if they had had more time "all the groups would have come up with the solution because they were getting very close and having success with the strategy they used."

Cathy shared last. She expressed how she saw her students using many strategies to solve this activity, but that she did need to provide some assistance in the beginning to get them started. In addition, she explained that the class had had a lengthy discussion about their strategies at the end of the class and were thinking about an extension she had given them where three instead of two colors were used.

We spent the last part of this meeting reviewing all of the problem-solving activities that were implemented and discussing ways the activities might be adapted, modified, and extended to be used across many grade levels. We included this step because every PLC group at the research site was required to share their accomplishments at the beginning of the following school year with the rest of the school. We decided to share the activities and their implementation processes with the entire staff at a professional development meeting. Throughout this discussion, each

member contributed novel ideas and thoughts. The members were creating an environment where they could learn from one another just as students do when they share their different strategies and thinking processes for working on the same problem-solving activity.

As noted from the videotape, after the implementation of the third problem-solving activity and the sharing and discussions during the fifth PLC meeting, it appeared that Emma and Cathy had changed some of their implementation strategies as well as their beliefs about these problem-solving activities. Emma continued to take on more of a facilitator rule in her classroom, she provided less information to the students at the beginning of the lesson, and moved to focus on the students' thinking processes and strategies rather than a correct solution. Cathy noticed that sometimes her students might need extra guidance to get started; she also extended the wrap-up discussion, looked for ways to lengthen the activity, and asked students to make connections between the activity and mathematical concepts used to solve the problem. In addition, as noted from the videotape, both participants started to realize how to integrate these activities into the regular mathematics curriculum.

Post Professional Learning Community

From the post interview and a final classroom observation, I gathered data about each participant's beliefs, knowledge, and instructional practices in regards to mathematics teaching and learning and problem solving. I deliberately included some of the same questions in the post interview that I had asked in the pre-interview to help me determine if the participants' beliefs, knowledge, and instructional practices had changed.

In addition, I included questions about the participants' year-round professional learning community. (See post interview guide, Appendix B).

During the analysis of the pre-interviews and two classroom observations in the beginning of the year, as noted earlier, five categories emerged: school experiences, student learning, planning and instruction of mathematics lessons, decision-making influences, and incorporation of problem solving. To compare each participant's own start- and end-point beliefs, knowledge, and instructional practices I omitted the school-experiences category in my analysis of the post interview and final classroom observation. This category was not a focus at the end of the year because these experiences were static; no new information had been added since the pre-interview. Hence, there was no comparison to be made between start and finish.

I did add one new area, professional learning, to the post interview. I asked specific questions about the year-round professional learning community to ascertain each participant's feelings and thoughts about the experience as well as how it compared to other professional learning experiences they had had. In the field of mathematics education, such information can help teacher educators improve professional learning experiences designed to influence teachers' instructional practices.

Due to this addition, a new category, which I called *future practices*, emerged during my analysis of the interview data. This category surfaced as the participants spoke about how their learnings that year would influence their future instructional practices and/or advance their pedagogical knowledge about mathematics. This section explains

each participants' beliefs and instructional practices as they relate to the six categories detailed above.

In summary, the section on each participant below provides a description of the data collected during the post interview and final observation. In Chapter 5 comparisons will be made within each participant's answers and between both participants.

Emma

As noted from the videotapes of all five PLC meetings, spanning the entire academic year, Emma was very reflective about her experiences with teaching and learning mathematics, especially problem solving. As a result, during the post interview she had a lot to talk about. Those thoughts, feelings, beliefs, and knowledge are described in the sections below. Further, I made a final classroom observation to see if what Emma spoke about was actually carried out in her classroom. Her instructional practices and actions during that observation are described as they relate to the five different categories.

Student learning. During the pre-interview, Emma indicated that, for her, for a lesson to ensure student learning, it must be related to real life and engaging; foster student ownership of learning; involve manipulatives; and include informal, mini assessments. (Despite this stated belief, I observed none of these features during the two observations of her teaching at the beginning of the year.) Emma spoke of all of those aspects again during the post interview, but put a heavier emphasis on relating mathematics concepts to the student's life, or as she termed it, "applied math." For example, when the students were studying percentages, she had them do several real-life activities involving sales tax, tips, and discounts. The students brought in advertisements

and receipts from home and performed various calculations using this information. She noted, "It was really intriguing to see the students bringing in receipts and making that connection with the math that they were learning. . .understanding now how the price was calculated."

Further, Emma touched upon student ownership of their learning again, but spoke of it more in the sense of allowing the students choice and an opportunity to discuss/explain their thinking and strategies with one another. She referenced this idea when speaking about using problem-solving activities in the classroom:

> As the year went on, during problem-solving activities I allowed the students to choose a strategy without really giving them any guidance and then work through the problem. . .during this time I would walk around the room and ask the students/groups to explain what they were doing and how this strategy worked. . .[finally] the students would discuss [their strategies] as a whole group. This discussion, I feel, was successful because the students were exposed to more strategies and [thus] would have more to choose from in the future.

Emma continued by saying it was difficult at first for her to step away and let the students work during the problem-solving activities. In addition, she noted that it was sometimes challenging for the students to know where to begin working on the problem-solving activity. However, as students were continually given autonomy for their learning over the year, Emma noticed that having more choice seemed to result in more enthusiastic and engaged students.

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While observing Emma teach at the end of April, I noted that some of her beliefs about aspects of a lesson that would ensure student learning were reflected in her lesson, (As mentioned above, none were evident at the beginning of the year during the two initial observations.) In this lesson, students were learning how to subtract integers. Emma demonstrated this process by using transparent, colored chips on the overhead and giving the students opaque, two-sided chips to represent positive and negative numbers. She then had the students work with partners to complete a handout on this concept, which they could do either with or without the aid of the chips. Emma's lesson incorporated manipulatives; engaged the students; called for work in pairs, which could promote discussion; and allowed her to walk around the room and converse with the various pairs. This classroom was very different from the one I observed at the beginning of the year where the students sat quietly at their desks listening to Emma and/or working out problems individually.

Planning and instruction of mathematics lessons. During the post interview, Emma mentioned several of the same planning-related topics that she had brought up in her pre-interview. First, she still relied on the textbook, but she commented that she was now more knowledgeable about the sixth-grade mathematics curriculum and the textbook's pros and cons. She was now clearer on when she needed to supplement with other resources . Specifically, Emma explained:

> I read over the lesson in the book to see what they say I should do. Then I
>
> go. . .[to] the Internet to look up those topics and see how they have been taught
>
> in other ways. I then see what the school has to offer for manipulatives. . .I see if I

can make my own SMART Board lesson, or what SMART Board lessons have already been made. Again I am on the search for making it as interactive and engaging as possible.

During the observed lesson, Emma did, in fact, rely somewhat on the textbook to introduce the concept of subtracting integers. However, the two-sided chip idea came from a colleague, and she retrieved the practice problems from the Internet.

Emma also reiterated how she enjoyed planning with other teachers, both those at her grade level and those from different grade levels (whom she encountered during the PLC meetings). Emma stated, "The insight of other teachers [is important], I think . . . someone like myself benefits in the classroom because I do firsthand take back and apply what I am hearing and learning from other teachers."

Further, Emma had described earlier in the year a specific format she followed when planning a lesson: homework review, warm-up, lesson activity, and closure. She did not specifically mention this format again in the post interview, but based on my classroom observation it seemed this format still existed: The students first went over the answers to their homework, then during the lesson activity Emma introduced the concept of subtracting integers and the students practiced, and finally the students ended by going over the answers to the practice problems and resolving any misunderstandings that they may have had. The only feature that was missing in this lesson (compared to her earlier description) was the warm-up activity.

To these three components of planning, which Emma had been using since the beginning of the year, she added two new influences on her decisions: students'

background knowledge and her own awareness of different strategies. She explained that throughout the year she had learned more about the mathematical concepts taught in fifth grade (by reviewing the fifth-grade pacing guides and from talking with PLC teachers), including what knowledge the students entering her classroom should have. Emma stated that she now has "a better gauge of the [students'] abilities, granted every [student] is different and every year the set of [students] is different, but at least I have some type of playing field to begin with." In essence, she claimed that she has learned throughout the year from her students about what mathematical concepts are easier or harder to grasp; which concepts are more effectively taught using visuals, manipulatives, and real-world scenarios; and common misunderstandings students may have about certain concepts.

Lastly, Emma indicated that she learned that there are many different strategies that students can and do use in solving problems. She explained that she felt that it was important for the students to learn various strategies so they would have choices when problem solving. She added that it was a good idea to allot time during a lesson for students to explain the strategies they have chosen. As a result of these beliefs, Emma indicated that she had started to teach different strategies and allow students to share more and that she was planning to incorporate these features at the beginning of the next school year.

Decision-making influences. During the pre-interview, Emma was asked to discuss influences she felt were affecting her decision-making processes while planning and conducting a mathematics lesson. Emma stated that the biggest influences were the mathematics SOLs, her students' academic levels and learning styles, and lack of

resources. The same question, posed at the post interview elicited a slightly different response. Emma explained that after teaching sixth-grade mathematics for a year, she had gained an understanding of what the students are "required" to learn (e.g., the Virginia SOLs), a "better gauge of the [students'] abilities and background knowledge," and a clearer sense of available resources. Emma felt that this new knowledge had liberated her to spend more time making her lessons interactive for students by using more visuals, hands-on materials, and SMART Board activities. Emma explained:

> This year has been a huge enlightening experience as far as learning the curriculum, understanding what my students learned in fifth grade, gaining more resources, and learning what type of lessons are more effective. . .so therefore I figure out what concept I am going to teach, read over the lesson in the textbook, and then look through the other resources I have like the Internet, SMART board lessons, manipulatives, and so on. Again I am trying to make the lesson as interactive and engaging as possible.

In sum, Emma seemed to have moved away from using the SOLs as her main guide to planning lessons to a focus on creative and interactive lessons, which still succeed in teaching the required concepts.

Incorporation of problem solving. Based on Emma's comments during the pre-interview, it appeared that she incorporated problem solving at the beginning of the year only by using the two word-problem lessons included in each chapter of the textbook. She would present a problem-solving strategy then give the students several word problems to practice using this strategy. However, during the post interview when I asked

Emma about how she incorporated problem solving into her classroom, she spoke at more length. First, she stated that she found "that teaching problem solving was much easier taught integrated rather than separated or better taught throughout lessons." She elaborated by indicating that she thought the "textbook did a relatively good job with at least supplying me with some word problem activities to do that related to each topic but not all were very effective."

Second, Emma explained how she was surprised by all the different strategies students used to solve the same problem-solving activity. At the same time she noted, "Although there are many different strategies I saw that many students latch onto one or two particular strategies. . . .I think this needs to be addressed and the students need to become aware of various strategies." Emma continued to explain that these various strategies could be shared at the end of a problem-solving activity via group discussion, which would give students the opportunity to hear about their classmates' strategies.

Third, Emma stated that she felt the most effective problem-solving activities were ones that the students could apply to their own lives and use which called upon their prior mathematical knowledge. Emma said that "The Budgie" problem-solving activity that she implemented exemplified these qualities:

> The Budgie problem was pretty involved since the students were given the price
> of three types of birds and they had to figure out how many of each type of bird
> they needed to buy in order to spend $100 and buy 100 birds. . .while this activity
> required prior knowledge, a logical strategy, and quite a bit of time, the students

seemed very engaged because it was related to real life and [they were] motivated

to figure it out.

Fourth, Emma remembered that earlier in the year she would first teach a

particular problem-solving strategy and then allow the students to work on problems. Her

experiences in the PLC helped her evolve: "The [PLC] group gave me the idea to let [the

students] on their own and choose their strategy. . . .I realized by doing this, that

[problem-solving activities] are more about the student's strategy and their explanation

rather than their answer."

Emma concluded this part of the discussion by stating that she now felt more

comfortable doing problem-solving activities in her classroom. She attributed this

change to having more resources (referring to the two books used during the PLC), the

students' high level of engagement in these activities, and her awareness of how

effectively these activities encouraged discussions amongst the students. Emma added

that she especially liked that the process developed students' knowledge of a variety of

strategies.

Professional learning. I asked during the post interview what Emma thought

about her year-long professional learning experience. She had only positive things to say

and based these statements on comparisons with her other professional learning

experiences. Emma stated several times during the interview that she felt this PLC was

very successful for numerous reasons: (a) It applied directly to her classroom activities.

(b) It was year-long so she was able to implement an activity and then reflect on it. (c)

The small group of teachers with similar interests resulted in a lot of sharing with and

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learning from one another. (d) Many resources were provided throughout. (e) The topic interested her. (f) She chose to participate in the PLC, rather than being "forced" to. And, (g) the meeting times were built into the workday so no time outside of school was required.

Future practices. Throughout the interview Emma brought up her plans for future years. She spoke at length about keeping track of the various strategies the students use while working through problem-solving activities: "I would like to record as we go through the year, the strategies that [the students] use on a poster. . .so it's visible for them and so they have a source to pull from." She reiterated though, that she planned to continue to allow students to choose their strategies, but, at the same time, she wanted them to be aware of other possibilities.

Emma mentioned two additional plans for the future that would increase her pedagogical knowledge and resource base. She would like to take more of the professional development classes on incorporating problem solving into the classroom offered by her school district. In addition, she would like to learn more about the various manipulatives available and how best to use them.

Summary of beliefs, perceptions, and instructional practices. It was clear from Emma's post interview that several of her beliefs about student learning, and planning and instruction of mathematics lessons were similar to those she had held at the beginning of the study. She did, however, develop an appreciation of the importance of student ownership of learning and student choice. Emma's new belief in the need for discussion so that students could explain their thinking and processes had become a

priority for her. Most importantly, Emma did not simply give lip service to these beliefs; I saw them in play during my observations of her mathematics lesson. This was not the case in the beginning of the year. Overall, Emma's beliefs about student learning and planning and instruction aligned with the reform view of teaching mathematics.

Similarly, Emma's new beliefs about incorporating problem solving and practices followed the reform beliefs. She now felt that problem-solving activities should be integrated throughout the mathematics curriculum, should focus on allowing students to choose their own strategies, should include time for students to share their strategies, should be related to the students' lives, and should focus on student processes for solving the problem, rather than on the correct answer. These beliefs align with NCTM's (2000) and PISA's (2003) definitions of problem solving.

Cathy

The videotapes of the PLC meetings showed that Cathy reflected less on her experiences with teaching and learning mathematics than did Emma throughout the year. However, Cathy did have more experience in teaching mathematics (her third year versus Emma's first year in teaching math, following three years of teaching science) and she said her mathematics method classes had had a lot of discussion about problem solving. Yet, during the post interview, Cathy did express several thoughts, feelings, beliefs, and knowledge about teaching mathematics in general and incorporating problem solving. In the next section I describe these as well as her instructional practices and actions as they relate to the six emergent categories in the study.

Student learning. As noted earlier, the beliefs Cathy expressed during the pre-interview about the important features of a lesson to ensure student learning were: (a) note pages should be provided, (b) students need time to practice what they have learned, (c) students should be taught why they are learning a concept and how it can be used in their lives, (d) hands-on activities should be included, and (e) students should be shown various ways/strategies to solve a problem. During my two observations in the beginning of the year, I saw that Cathy had incorporated these features into her lessons.

During the post interview, Cathy spoke primarily about the importance of using hands-on activities (e.g., manipulatives) and teaching students mathematical concepts via a connection with real-life situations, which she referred to as a type of problem-solving activity. Cathy gave an example of using manipulatives when teaching subtracting integers. (The same concept that I observed Emma teaching):

> I recently taught my students subtracting integers. I used two-sided counters the entire time and it did wonders. They actually understood subtracting integers, where in the past I simply taught them the rule, 'leave, change, change'. . .they would apply it yet they did not truly understand what they were doing. With the counters I felt they understood the concept and therefore could understand why 'leave, change, change' works.

Cathy went on to say that, given the difficulty of mastering the concept of subtracting integers, she had decided that the manipulatives would best meet her students' needs.

Cathy next gave an example to illustrate how relating concepts to a real-life situation can help the students better understand why they are learning this material:

Most recently I did a review with box and whisker plots because my students

forgot what they were and how to create one. . .Earlier in the year, I taught them

the steps in making one but not really why they would use it. I got the idea from

the NCTM website to use an activity from the Illuminations [NCTM-created

website with hundreds of digital lessons for grades K-12 that are aligned with the

new Standards]. . .the students looked at the Houston Rockets and how it had Yao

Ming [basketball player] in the set [of data] versus having him out of the set [of

data]. Further, I explained to them that when creating box and whisker plots, you

are not looking at the mean but rather how the data are distributed. . .[overall] it

was a nice way for [the students] to see how what they are learning in math class

can be used in real life and as a result I think they will remember better how to

create a box and whisker plot.

While observing Cathy teach in the middle of April, I noticed again that she

successfully incorporated the features that she felt were most important to student

learning. For this lesson, Cathy began by going over the answers to the previous night's

homework on permutations and combinations. The students had been taught both relevant

formulas previously, but were confused over which formula to use when. Cathy made

several connections for the students, one being to the "Decoration Delight" problem-

solving activity. The students had worked on that problem earlier without knowing the

formulas for combinations and permutations. Cathy had the class revisit the activity after

they had learned the formulas so they could see another way of solving the problem.

The other connection was showing the difference between permutations and combinations. Cathy explained that if she wanted to figure out how many different ways she could arrange 10 of the 25 students in the classroom in a straight line, she would need to consider order. However, if she just wanted to know how many different teams of 10 she could make with the 25 students, order was unimportant. (Once 10 people were assigned to a team, those ten could not make up a "different" team). Lastly, she stated that in permutations, order matters, while in combinations, order does not matter. By doing this, Cathy gave the students examples that they could relate to and something to think about/reference.

Lastly, in this lesson, Cathy gave the students Pascal's Triangle and showed them how to use it to quickly find an answer to a combinations question. Afterwards, she asked the students to look for other patterns in Pascal's Triangle because the next day they were going to discover additional ways to use this triangular array.

In this lesson, Cathy related the student's mathematics to real life, made connections to previous mathematics experiences, used visuals (Pascal's Triangle), and showed the students various ways to answer one question. All of these instructional strategies were techniques that Cathy felt were important to student learning.

Planning and instruction of mathematics lessons. Like Emma, during the post interview Cathy brought up several of the same planning concepts that she had spoken about in her pre-interview. Originally, Cathy had mentioned how she relied heavily on the district's pacing guides, based on the Virginia SOLs. She then used the standards to align the concepts with the chapters in the book and then developed her lessons.

However, now that the year was almost finished, Cathy felt that she was more familiar with what concepts needed to be taught and, therefore, she did not feel the need to rely so heavily on the textbook. Further, after becoming aware of other resources like the Illuminations curriculum and the NCTM website, Cathy knew that she could use resources like these to help plan and create lessons that were more related to real life and required higher-order thinking skills.

During the observed lesson, Cathy's only use of the textbook was as a source for practice problems for the previous night's homework. She created her own connections and examples, and she found the idea for the Pascal's Triangle activity on the Internet. After discussing the issue of reliance on pacing guides and the textbook, Cathy restated:

I definitely have a lesson to teach and then an activity that follows. . .but it depends on the concept and if I feel like it is something that needs more to the lesson, like when I taught subtracting integers. The textbook did not suggest using manipulatives [two-sided counters], but I felt it was necessary in order for the students to fully grasp the concept.

In sum, Cathy used the pacing guides and textbook to assist her somewhat, but her knowledge and experience with the students and the curriculum were becoming the prime influences on her planning. This development was evident during the final observation. Cathy did not use the textbook to plan her lesson on permutations and combinations, and based on the students' questions and confusion, she spontaneously provided examples and connections to help clear up any misunderstandings.

Something new for Cathy was the idea of collaborative planning; she thought it would be easier than planning on her own and would like to work with other teachers to plan lessons. Cathy stated that:

By collaborating it would make it much easier to plan more effective lessons that incorporate more problem solving and hands-on activities because with more people involved in planning there are more resources that can be looked at and less time taken by one teacher to do so.

However, she did acknowledge that collaboration could be difficult to organize due to the lack of common planning periods.

Decision-making influences. During the pre-interview, I asked Cathy to explain what influenced her decision-making processes while planning and conducting a mathematics lesson. Cathy said her biggest influences were the pacing guides, making sure her lessons had a hands-on activity, and trying to teach the students various ways to solve the same problem. I asked the same question during the post interview, and like Emma's, Cathy's second answer was slightly different from the first. While Cathy still relied heavily on the pacing guides, she felt that she had developed "a better handle on what is to be taught and when." As a result, she was able to explore other resources, besides the textbook, that could be used to teach her lessons. Cathy stated:

In the beginning of the year I was just trying to get the material out to the students and the easiest way for me to do that was to use the pacing guide which directed me to the lesson in the textbook. . . .However, by the end of the year I came across a lot more resources that I could use and liked better. . .so when I am about

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to teach a certain topic, say box and whisker plots, I now know that instead of teaching like the textbook suggests, I can use the problem-solving activity I found in Illuminations.

Another new decision-making influence that Cathy mentioned was her students: "In thinking about the concept I am going to teach, I try to think about the students and where they are at and what would help them versus confuse them." In essence, Cathy was now thinking about the different strategies that work best for her students. When I asked Cathy how she gathered this information, she explained that she observed her students and that the more time she spent with them, the easier it became to know their needs. Further, she stated, "I try to check in with them and see where they are at and what things make sense to them and definitely things that don't work. . .based on this information I may make a decision to revisit a concept."

Lastly, a huge influence that Cathy mentioned was time. She stated, "My goal is to get through [all the material] by May so that I can review with the students and get them ready for the SOL test." She felt that because of the strong pressure on teachers to get all their students to pass the state assessments she was always racing against the clock to teach all of the material.

In sum, while the pacing guides influenced her instruction and she saw time as an obstacle, by the end of the year Cathy was trying to move away from using the textbook as much and towards other resources in an attempt to create more effective lessons (e.g., the use of Illuminations, mentioned above, to teach the box and whisker plot in a

problem- solving manner). In addition, she started using the students' feedback and level of understanding to guide her teaching.

Incorporation of problem solving. Like Emma, and based on Cathy's comments during the pre-interview, Cathy initially incorporated problem solving by using the problem-solving activities in the textbook. Additionally, she explained that she had been influenced by another teacher (one she had taught with the previous year) who believed that problem solving should be taught after mathematical concepts. Further, Cathy mentioned during the pre-interview having other resources at her disposal, like *Problem Solver* (Moretti et al., 1987), but she never really had the time to look through them and/or implement them due to the amount of material she needed to cover. However, during the post interview when I asked Cathy about incorporating problem solving into her classroom, much had changed.

First and foremost, during the post interview, Cathy expressed how important she thought problem solving was: "I definitely believe that problem solving is a very important part of being a math student or mathematician because otherwise you're just following rote procedures." Despite this belief, she found it difficult to incorporate problem solving into her lessons because of her need to familiarize herself with the curriculum and being short on time and/or resources. However, Cathy claimed, "next year it will be much easier for me to incorporate problem solving on a more regular basis or to do as many lessons as I can." She reasoned that she now knew the curriculum, she had many more resources to pull from, and she had learned this year how to modify and extend an activity quickly.

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Second, Cathy spoke about the types of problem-solving activities that she

planned to incorporate next year:

Once in a while I might find something in the textbook, but those activities are

more concrete. . . .Instead I like to go to something like Illuminations, *Problem*

Solver [Moretti et al., 1987], or the NCTM site and also the two books that I

became aware of during the PLC meetings.

It appeared that Cathy was moving away from the textbook towards other resources. She

added that the problem-solving activities that she hoped to incorporate should involve

real-life situations.

Third, when I asked Cathy how problem solving should be implemented in the

classroom, her reply covered how and why:

I don't feel necessarily [that problem solving] should be incorporated at the

beginning, middle, or end [of the year] because I think it can be useful [to the

students] in learning how to do something as well as mastering concepts. . . .I

think it helps [the students] to understand the concept on a more concrete level

when you have to solve something. . . .You have to decide [which] strategy you

are going to use and then from there solve whatever it is that you are trying to

solve. . . .I think that students genuinely gain pleasure and enjoyment from

[problem solving]. . . .I think most people are curious and so when you are trying

to figure something out it makes that process all the more meaningful, purposeful,

enjoyable, and real.

Despite feeling problem solving was very important and that it offered many benefits for students, Cathy mentioned during the interview that she did fewer problem-solving activities with students who had lower math achievement levels.

Lastly, Cathy pointed out that through incorporating the problem-solving activities that she had chosen for the PLC, she became aware of how many different strategies the students used. As a result, she would like the students share their strategies because:

> If students are using the same strategy and that's all they're ever doing, then they are limiting themselves. . .maybe there is another [strategy] that they could [use] to approach a different problem or try using a different strategy with a similar problem they solved already.

Cathy expressed that this sharing could be done through discussion at the end of activities and the different strategies could be recorded.

Professional learning. As with Emma, I asked Cathy during the post interview what she thought about her year-long professional learning experience. Cathy thought that the entire experience was beneficial because she got to share her experiences with other teachers and learn from them as well as talk about specific lessons. She stated, "Everyone has a different way of presenting and organizing lessons and so it is really nice to hear suggestions of other teachers and try them out in your own classroom." Further, she explained that it would be very useful to continue in the same manner the next year; however, she felt it would be even easier if there were more than just two

teachers from each grade level teaching the same content, more like a team of teachers, but also noted the school was not set up for such a grouping.

Cathy then explained how this PLC was different from her other experiences with professional development:

> The other professional development or courses that I took were college-level math courses and math lead teacher classes. . . .I learned actual discrete mathematics in the college-level courses and during the math lead classes we talked mostly about assessments and testing, differentiating to meet the needs of students with learning disabilities and those second language speakers. . . .We did not specifically talk about lessons.

Although Cathy's overall experience with the PLC was positive and she thought it was beneficial, she made one suggestion for improvement:

> I would like to be able to discuss in our PLC how to incorporate problem-solving activities into the classroom on a regular basis. . . .This year we established what type of problem-solving activities we can do, implemented [them], and discussed our observations. . . .Now I think it would be great to sit down with the pacing guide/SOLs and pull from various resources to come up with problem-solving activities we can do throughout the year.

In sum, Cathy thought the PLC was successful and would participate again if the focus changed slightly.   .

Future practices. Cathy did not really talk about any plans for future practices except under the category of problem-solving. She stated that since she now had a really

good grasp on the curriculum and knowledge of the various resources that could help her develop problem-solving activities that "next year it will be much easier for me to incorporate problem solving on a regular basis."

Summary of beliefs, perceptions, and instructional practices. Cathy's post interview revealed that many of her current beliefs about student learning and planning and instruction of mathematics lessons were similar to the beliefs she held at the beginning of the year. In fact, all of Cathy's beliefs that aligned with the reform views were apparent during my observations in her classroom both at the beginning of the year and at the end of the year. The greatest difference that I noted between my first and last observations was that early in the year, her instruction mainly followed a traditional view of teaching mathematics. During the last observation, I saw a radical change: the students were no longer being lectured at, nor were they given notes and many similar practice problems to complete. Instead, the students were working together to understand the concept presented, given opportunities to discuss and ask inquisitive questions, and provided with an extension activity. These are all aspects of a reform way of teaching, which were absent from her classroom at the beginning of the year.

As far as incorporating problem solving into the classroom, at the beginning of the study Cathy simply taught the word problem lessons presented in the textbook. Additionally, she did understand problem solving as laid out by NCTM and PISA, but acknowledged that she had insufficient time to implement such activities due to curricular restraints. By the end of the study, Cathy realized she could integrate problem-solving

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activities into the daily mathematics lessons, and still have time to teach the required curriculum, but in a non-traditional way.

This chapter provided a detailed picture of each participant and described in depth the events of the year-long study. In summary, as noted in the observations, interviews, and videotapes, both Emma and Cathy demonstrated change in their beliefs, knowledge, and instructional practices with regard to teaching and learning mathematics. In addition, the post interview revealed aspects of the PLC that both participants found effective. Lastly, I endeavored to explain here my role as the PLC leader as well as the factors that influenced my decisions and actions. In the next chapter, I will further analyze the data to answer the three research questions.

CHAPTER 5: RESULTS: PART II

In this chapter I present a summary of the beliefs, knowledge, and instructional practices for both participants in order to answer research question number one (How do these teachers respond to a problem-solving PLC?). Each participant's stated beliefs (captured during formal interviews and informal discussions at the PLC meetings) will be described and then compared to what was actually observed during classroom lessons. Instructional practices (e.g., the participant's role during lessons, interactions with students, resources used, etc.) will also be described as observed during mathematics lessons throughout the year. Next, the factors that may have influenced the beliefs and practices of each participant will be explained to answer research question number two (What influences these teachers' decision making?). Then, a section will be devoted to discussing the similarities and differences between the participants' explorations during the entire study. Finally, the third research question will be answered (What are the decision-making processes of a teacher leader?).

Emma

This section provides answers to both research questions #1 and #2 in regards to Emma's participation in this study.

Results for Research Question #1

In this section I provide a detailed description of how Emma responded during a problem-solving based professional learning community. This description includes Emma's stated beliefs and observed actions from the beginning to the end of the study. The data set included a pre-interview, two observed mathematics lessons, five PLC meetings, three observed problem-solving lessons, one final observed mathematics lesson, and a post-interview. This section is divided into three subsections which coincide with the three phases of the data collection: (a) pre-PLC, (b) implementation of PLC and problem-solving lessons, and (c) post PLC.

Pre-PLC. Emma's initial stated beliefs and knowledge about teaching and learning mathematics as gathered from her pre-interview (October 8, 2007) were: (a) mathematics concepts should be related to the students' lives, (b) lessons should be designed which foster student's ownership of their learning (students should be engaged/actively involved), (c) manipulatives, various visuals, and oral as well as written explanations should be presented during lessons in order for teachers to address the various learning styles of their students, (d) mini, informal assessments should occur regularly as well as final formal assessments, and (e) problem solving in mathematics is separate from the general mathematics lessons and involves students being taught a specific strategy and being given simple word problems to practice that strategy. As for her instructional practices, Emma stated that she designed her lessons using the state's standards of learning (SOLs) and the textbook as resources. Further, she indicated that

each lesson followed a specific format: homework review, warm-up, lesson activity, and closure.

During my two observations of Emma's mathematics lessons (October 5, 2007 and November 9, 2007), hardly any of her stated beliefs were apparent. The students sat at their desks and listened to Emma lecture; she taught specific algorithms or strategies to use with the mathematics concept they were learning. The students then independently practiced in class what they had been taught. The lessons were not related to the students' lives, they did not seem engaging (students only listened and then worked independently), and they did not appear to foster student ownership of their learning. Emma did not informally assess each student's understanding during the homework review as she gave them the answers to check their work individually. Further, there were no warm-up activities or closure exercises observed. The sole attribute of the two lessons reflecting Emma's stated beliefs was her incorporation of visuals to accommodate the visual learning style of some of her students. Such visuals used were the SMART Board and different colors to represent the different place values during long multiplication demonstrated on the white board in front of the class. In summary, at this point in the study, Emma's observed actions (which reflected a fairly traditional view of teaching mathematics) did not support her stated beliefs (which coincided with a reform view of teaching mathematics).

Implementation of Problem-Solving Based PLC and Problem-Solving Lessons. To facilitate data management and analysis, I divided the second phase of data

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collection into three subsections. This organization is mirrored in the discussion of my results below.

Section 1 (October-January). Following the pre-interview and observations, Emma participated in the first two PLC meetings. From these meetings, I gathered more information about her stated beliefs in addition to comments and questions about the topics discussed during the meetings. The first PLC meeting (October 15, 2007) focused on providing information about problem solving (how traditional views varied from current reform views), the effect of problem-solving lessons on student achievement as seen through research studies, and examples of problem-solving lessons that correspond with reform views.

During this meeting, Emma expressed her beliefs and thoughts and commented on the information provided. First, Emma was very focused on having the correct answers for the activities as well as knowing that students would get to the correct answers. Second, she stated that although she felt these problem-solving activities were very time consuming, they did capture best practices, such as engaging students, supporting group work, promoting conceptual understanding of mathematics concepts, relating to real life, and encouraging the use of manipulatives. Third, Emma also noted that she believed these activities encouraged students to learn predominately from one another via discussion rather than from the teacher, who was freed up to be a facilitator. Lastly, she believed that it would be difficult to simply let the students come up with their own strategies to solve these problems; instead, she envisioned teaching some strategies beforehand. In sum, Emma showed an interest in problem-solving activities and an

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understanding of how they could be beneficial for the students. However, she thought the implementation and the actual process of students' solving the problems and getting the correct answers would be very difficult to achieve.

During the second PLC meeting (November 19, 2007), the participants considered more problem-solving activities in order to design/adapt an activity to implement in their own classrooms. Although the majority of the time was used in design, Emma did express some beliefs, comments, and concerns. First, she suggested that these activities could be given to students who finished their class work early rather than to the class as a whole. However, since these activities were designed for the whole class, Emma then asked questions about implementation: (a) Would the activities be done in groups and, if so, how many students per group? (b) Where was the correct answer for these activities? and (c) Would there be teaching prior to working on the activity? Lastly, Emma again stated that she questioned/doubted the students' ability to explain how they arrived at the solution to such a problem-solving activity. At this point, Emma was still focused on the correct answer rather than the process students use to arrive at an answer; she also was concerned about the students struggling through such activities and questioned the implementation. By the end of the meeting, the group had adapted a problem-solving activity, and each participant agreed to implement it in her classroom and share observations with the group during the third meeting.

Emma implemented the activity, "Decoration Delight," on December 4, 2007. The following describes the implementation tactics and actions I observed in Emma's classroom during the problem-solving activity. First, Emma ensured that all of the

students understood the "big question" or task at hand. Second, she focused the students

on the letter to be written at the conclusion of the activity (in which the students were to

explain the thought processes and strategies they used to find their solutions and to justify

their answers). Third, she did not provide the students with any manipulatives. Fourth,

Emma did put the students in groups of four, but during the activity the students mostly

worked independently or with a partner in the group. Fifth, Emma visited each group,

often providing ways for the students to solve the problem and/or strategies to use. Sixth,

for each question, she stopped the class and conducted a whole-group discussion of

misunderstandings. Lastly, at the end of the class period, there was no discussion about

the activity; students ended by simply handing in the letter, and Emma provided the

correct answer before dismissing the students.

Overall, Emma's implementation of this first problem-solving activity reflected

two of her beliefs stated during PLC meeting 1 and meeting 2. First, she was focused on

the correct answer and, therefore, she centered the activity on the explanatory letter that

the students were to write. In addition, she quickly told the students the correct answer at

the end of class with no whole-group discussion about strategies, processes, etc. Second,

because she thought it would be difficult for the students to come up with a strategy and

work with very little guidance, as she circulated from group to group, she told students

how to solve the problem and what strategy (or strategies to use), interrupting the group

work to clear up misunderstandings for the class as a whole.

After implementation of the first problem-solving activity, the third PLC meeting

(January 7, 2008) was held and the participants discussed how they had implemented the

activity and what they had observed. During the meeting, Emma listened closely to the other teachers and, as a result, she stated that she realized that she had provided more assistance to her students than the other teachers. Further, she expressed curiosity about how her students would have done with less assistance. Lastly, reflection on her implementation and comparing it to the other teachers' led to her stated decision to try and provide less guidance during the next implementation.

     Section 2 (January-February). Shortly after the third PLC, Emma implemented a second problem-solving activity (January 16, 2008) that she chose and adapted for her students. In this activity, "What Shapes Can You Make," the students were instructed to form as many shapes as possible with four isosceles triangles. Emma began the activity by providing a brief introduction and explanation of a few terms, such as *congruency*, and again ensured that the students understood the task at hand. Next, Emma provided tangrams (a manipulative) for the students to use if they so desired. Then, she let the students pick a partner and get to work. While the students were working, Emma walked around to each pair, observed what they were doing, asked questions about their thinking, and provided some guidance if asked. Lastly, Emma concluded this activity with a whole-group discussion on the student's solutions and shapes that they had come up with. Overall, I observed that Emma provided less guidance than in previous lessons and asked the pairs what they were doing and why.

     Similar to PLC meeting 3, the participants discussed their implementation and observations of their second problem-solving activity during PLC meeting 4 (February 11, 2008). Since each participant had chosen her own problem-solving activity, each

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spoke in more detail about what she had done this time and why, as well as what they might do during the third activity. Emma was again very reflective. First, she explained that during implementation she took on a facilitator role and allowed the students to be more creative, rather than guiding them in one direction. By doing this, she saw that the students generated several solutions and used different strategies to solve the same question. She continued by stating that she had now realized the importance of focusing on the student's strategies and processes rather than on the answer. Next, Emma elaborated on how she had given less information to the students this time, yet they had still been able to succeed (disproving her earlier statement that students would have a difficult time if they were not given sufficient information). Lastly, Emma stated that she could use this problem-solving activity as an introduction to her geometry unit and then refer back to it throughout the unit. Emma's responses varied significantly from her earlier thoughts about giving such problem-solving activities to early finishers only.

Section 3 (March-April). Emma implemented the final problem-solving activity that she had chosen, "The Budgie Problem" on April 2, 2008. For her introduction this time, Emma limited herself to reading the problem and explaining that a budgie was a bird. The students worked in groups of three or four, and Emma walked around to each group asking probing questions about what they were doing. There was no final whole-group discussion as time had run out. Discussion mainly occurred between students in their own groups as well as with Emma when she worked with each group. One group came up with the correct answer, which they shared at the very end, but Emma had all the groups hand in their closest answer as well as the work that led to their solution.

Finally, on April 21, 2008, the last of the PLC meetings occurred (PLC meeting 5). Again, the participants discussed their implementation styles and observations. Emma reiterated that these problem-solving activities could be used to introduce a unit or single concept in mathematics. Then she commented that, during the third problem-solving activity, she had observed her students struggling at first, but she refrained from providing assistance or an answer right away as she would have done in the past. As a result, she stated that by letting the students struggle a little, she had enabled them to come up with strategies that made sense to them and then they were able to work towards a solution. Lastly, she acknowledged that only one group got the correct answer, but she felt that with more time everyone would have come up with the solution.

In summary, at this point in the study (after implementation of the PLC and problem-solving activities), Emma's stated beliefs during the meetings and observed actions during the problem-solving activities coincided more closely with one another. As a result, I observed from the changes she made to her implementation of the problem-solving activity in her classroom after the meeting that she had taken her reflections and comments to heart. Clearly, Emma's stated beliefs and observed actions (instructional practices) were evolving towards consistency with reform views.

Post PLC. I observed a final mathematics lesson on April 30, 2008. Emma's actions during this lesson were consistent with several of her stated beliefs. First, she provided the students with manipulatives so they could conceptually and visually understand subtracting integers. Second, discussion was promoted by work in pairs. Third, Emma took on a facilitator role where she hardly lectured and, therefore, the

students were engaged in and owned the activity; ultimately, they were responsible for their learning. Lastly, the lesson plan format that Emma had laid out during the pre-interview was still present, but in a less rigid form. In sum, at the beginning of the study I noted during my first two observations that the beliefs Emma espoused during the pre-interview were not reflected in her actions in the classroom. I did, however, see evidence of those stated beliefs during the final observation.

Emma expressed her stated beliefs and knowledge about teaching and learning mathematics for the last time during her post interview on May 12, 2008. One of her stated beliefs was exactly the same as one of her pre-stated beliefs: that mathematical concepts should be related to the students' lives. The final statement of her belief about student ownership was similar to what she had said in the beginning interview, but Emma elaborated by stating that student ownership could come from allowing students to choose how they would solve a problem, followed by a discussion of their thinking and strategies. Emma stated two beliefs about problem solving during the post interview: (a) Problem solving should be integrated throughout the year and not taught separately from other mathematics. And, (b) problem-solving strategies do not need to be taught prior to a problem-solving activity, but should be shared via a whole-group discussion at the end of the activity.

As for her instructional practices, Emma stated that the SOLs were no longer the main influence on her planning (due to her increased familiarity with them); her focus was now on creating interactive and engaging lessons. Further, as stated earlier, while her only resource had been the textbook, she now also used the Internet, SMART Board

lessons, discussions with other teachers about planning and instructional methods, and learnings from her students. Lastly, Emma did not prescribe a specific lesson plan format as she had in the pre-interview.

Results for Sub-Questions A and B of Research Question #1

I provide answers to sub-questions A and B here, detailing how Emma's beliefs and instructional practices changed throughout the study.

How did Emma's beliefs change? Throughout the study, I observed that Emma's beliefs evolved, some more significantly than others. Emma stated several beliefs in the beginning of the study that she again stated at the end. Such beliefs were: (a) mathematics should be related to the students' lives, (b) students should be engaged in and have ownership of their learning, and (c) lessons should incorporate the various learning styles of students and therefore include manipulatives, visuals, and oral as well as written explanations. I actually began to observe the changes in her stated beliefs, as reflected in her lessons, starting in the middle of the study and continuing through to the end.

The most significant change in Emma's beliefs related to problem solving, strategies that students used, student learning, and teacher planning. In the beginning of the study, Emma's stated beliefs about problem solving were: (a) problem-solving activities should be taught separately, possibly by giving them to students who finish class work early; (b) to teach problem-solving activities, the teacher explains the appropriate strategies and then the students practice the strategies with simple word problems; (c) the focus of problem solving is getting to the one, correct answer; and (d)

students require a lot of guidance when working on problem solving. Emma summed up her changed beliefs about problem solving during her post interview: (a) Problem solving should be integrated throughout the year. (b) Such activities could be used to introduce a mathematics unit and possibly referred to throughout that unit. (c) Rather than the correct answer, the focus should be the strategies and processes the students use to arrive at a solution. And, (d) students do not need a lot of guidance during these activities.

Emma's beliefs about student strategies and learning were linked to problem solving. She believed originally that specific strategies should be taught before introducing problem-solving activities, because the students did not have a large knowledge base to pull from, and would, therefore, be frustrated by problem-solving activities. However, by the end of the study, Emma had seen that students did have a lot of strategies they could use so it was unnecessary to teach strategies ahead of time. In addition, she believed that students should be exposed to other strategies via class discussion and hearing classmates explain their strategies. She made no mention of students' learning through discussion in the beginning of the study; however, by the end she believed that discussion was an integral part of student learning. Further, at the end of the study she believed that, although students may have difficulties at the beginning of a problem-solving activity, they learn best and take pride in their learning by persevering and finding a strategy that works for them.

Finally, in the beginning of the study Emma believed that her planning should be determined by the state's SOLs, she should use the textbook to design lessons, and she should use a specific lesson plan format for every lesson. By the end of the study, Emma

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no longer believed that the SOLs should drive her instruction, but serve more as a guide; the textbook should not be her only resource, and all lessons did not have to follow the same format. Instead, she believed that her focus should be on making her lessons as engaging and interactive as possible and that resources should include the textbook (but not be limited to it), other resources like the Internet, other teachers, and learnings from her students. Lastly, she believed that lesson plans did not have to follow a rigid format.

How did Emma's instructional practices change? Throughout the study Emma's instructional practices evolved as well. These changes were seen in her mathematics lessons and in her the problem-solving lessons. At the beginning of the study, I observed during two of Emma's mathematics lessons, that her lessons were characterized by: (a) students sitting at their desks while she lectured; (b) Emma teaching an algorithm for that day's lesson; (c) students practicing using the algorithm independently with a set of similar problems; (d) use of some visuals (SMART board and different colors to represent different place values); (e) no clear relationship between the problems and the students' lives; (f) no hands-on activities, only paper-pencil tasks; (g) no discussion among the students; and (h) a lesson closure marked by assignment of that night's homework. By the end of the study, I observed the following changes during a mathematics lesson: (a) Emma did not teach an algorithm right away, instead she demonstrated the concept by using manipulatives; (b) Emma demonstrated rather than lecturing; (c) students worked with partners using manipulatives to figure out answers; (d) discussion occurred while the students were working with their partners; and (e) at the

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end of the lesson, the students discussed as a whole class the answers and what they had learned.

In summary, classroom observations, interviews, and videotapes indicated that Emma's instructional practices had evolved in three major ways. First, she moved from a lecture format, where she told students how to solve/understand a concept, to introducing a concept with manipulatives. In essence, the students learned via their own investigations, partner work, and discussion rather than through lecture and rote practice. Emma's role changed from one of lecturing to guiding. Second, Emma incorporated hands-on activities that had not been used in the two lessons at the beginning of the year. Third, I observed no discussion at the beginning of the year, whereas at the end of the year students had talked with their partners and also as a whole class. These are significant changes in Emma's instructional practices, as they appear to be moving her toward reform practices.

I also observed changes in instructional practices during the three problem-solving lessons. I noted four ways in which Emma's practice evolved. First, her role changed: She moved from telling the students how to solve the problem and what strategies to use when they were struggling to guiding them towards a solution by asking probing questions and inquiring about their thinking processes and strategies. Second, Emma provided no manipulatives/visuals during the first activity, but offered them as an option during the second and third activities. Third, she changed her focus in the problem-solving activities from the correct answer to the process students used and their interpretations of their solutions. Fourth, there was no conclusion or discussion at the end

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of the first activity; the students simply handed in their answers. The second and third activities included a closing whole-class discussion where students shared their solutions, thinking processes, and strategies. Overall, as a result of the year-long professional learning community, Emma's instructional practices in her mathematics classroom improved.

Results for Research Question #2

I answered the second research question (What influences these teachers' decision making throughout the year?) by gathering information throughout the year via pre- and post interviews and comments, reflections, and questions during the five PLC meetings. From the data analysis, I was able to distinguish five influences/explanations for Emma: (a) knowledge about the curriculum and instructional practices, (b) willingness to change and take risks, (c) ability to reflect about her own practices, (d) excitement about learning from other teachers, and (e) eagerness to learn from her students.

In the beginning of the study, Emma stated that she was not extremely familiar with the sixth-grade curriculum and, as a result, she relied on the state's SOLs as well as the textbook to plan lessons. At the end of the study, she said that as she became more knowledgeable of the curriculum and acquainted with additional resources, she was able to focus on making her lessons more hands-on, engaging, and appropriate for her students' learning styles. In addition, Emma came into the study with very little knowledge about problem solving in mathematics (e.g., what type of activities are considered "problem solving" and how can they be implemented in the classroom). As the study progressed, she gained a wealth of knowledge and was then able to more

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comfortably implement such activities. In sum, as Emma's knowledge about teaching and learning mathematics grew, her instructional practices reflected these new ideas and were implemented differently.

Next, I observed that Emma was very willing to take risks in her classroom and try new ideas to change her instructional practices. During the PLC meetings, Emma listened to the other teachers explain how they had implemented their problem-solving activities and then reflected upon what she had done in her classroom. Further, she commented about what she would like to try next or change. I did observe the changes that Emma spoke about trying during the problem-solving lessons that she implemented following each meeting. Emma's actions showed that she was able to reflect on her own practices and try new ideas that ultimately improved her teaching.

Emma explained during the post interview that many of the changes she incorporated into her implementation of problem-solving activities arose from other teachers' explanations of their teaching methods during the PLC meetings. Clearly, she enjoyed learning from other teachers; she said as much in the post interview, noting how she thought that one of the most beneficial aspects of the PLC was the opportunity to work with a small group of teachers and learn what they did in their mathematics classroom. She further commented that she enjoyed planning with teachers across grade levels because she could take these learnings back to her mathematics classroom. Emma would like to continue learning from and working with teachers of various grade levels.

Lastly, Emma commented during the PLC meetings that her observations of her students influenced what she did during the next problem-solving activity. She stated

that when she started to step back from helping the students and, instead, took on a guiding/watching role, she was able to learn from her students. As a result, she realized that her students could learn a lot on their own, rather than always being told how or what to learn. This awareness allowed Emma to make yet another change to her teaching style. In conclusion, these five influences on Emma were critical to the evolution of her beliefs and instructional practices during this study.

Cathy

The following section organization mirrors that of the previous section describing Emma.

Results for Research Question #1

Like with, I provide a detailed description of Cathy's stated beliefs and observed actions from the beginning to the end of the study. The data set included a pre-interview, two observed mathematics lessons, five PLC meeting, three observed problem-solving lessons, a final observed mathematics lesson, and a post interview.

Pre-PLC. Cathy's initial stated beliefs and knowledge about teaching and learning mathematics as gathered from her pre-interview (October 12, 2007) were: (a) mathematical concepts should be taught in multiple ways, and various strategies should be presented for students to use in solving/understanding a concept; (b) lessons should be designed to include hands-on activities; (c) students should have an opportunity to practice what they are learning during the lesson; (d) note pages should be distributed or students should take notes; (e) assessments should occur at the end of each unit; and (f) problem solving in mathematics involved students reading through a word problem and

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applying a known strategy to solve it. For her instructional practices, Cathy stated that she relied on the district's pacing guides and the SOLs to plan her lessons, and she used the textbook and other supplemental resources when designing the lesson. Further, she said that each of her lessons followed a specific format: homework review, warm-up, lesson, and independent or group practice.

During my two observations of Cathy's mathematics lessons (October 4, 2007 and November 8, 2007), I saw evidence of her stated beliefs. Cathy did provide different ways to solve a problem or allowed students to share their various strategies. In addition, a hands-on game, which reviewed previously learned concepts, did occur at the end of each lesson; students took notes; and there were opportunities for practice using mathematical problems related to real-life situations. Her lessons did follow her stated lesson format. However, although I observed the reflection of many of Cathy's stated beliefs in her lessons, during the majority of time in each lesson Cathy delivered instruction, while the students sat and listened or took notes. The only hands-on activities were the games at the end of the lesson; such activities were not used to teach that day's concept. In summary, at this time in the study, Cathy's observed actions did support her stated beliefs for the most part, but her implementation was minimal.

Implementation of Problem-Solving Based PLC and Problem-Solving

Lessons. As with Emma's data, the results are discussed in three sub-sections that mirror the sub-division of this phase of the data collection.

Section 1 (October-January). Following the pre-interview and observations, Cathy participated in the first two PLC meetings. From these meetings, I was able to

gather more information about her stated beliefs, specifically about problem solving in mathematics. The first PLC meeting (October 15, 2007) focused on providing information about problem solving and examples of problem-solving activities. During this meeting, Cathy expressed her stated beliefs, thoughts, and comments about the information. First, Cathy stated that she thought the problem-solving activities we examined in the PLC did not necessarily need to be presented at the end of a unit, but could be used as an introduction. Second, she said she liked the open-endedness of these activities, because they force the students to explain their thinking/processes while solving them. Third, she stated that these activities would encourage students to use their prior mathematical knowledge to solve problems and that they should be allowed to use any strategy that worked for them. Lastly, she indicated that she liked these activities better then one-step word problems because they were open-ended and focused on discourse and justification of a solution. In sum, Cathy communicated an interest in problem-solving activities, an understanding of how they were beneficial to the students' learning, and an idea about using them to introduce a unit.

During the second PLC meeting (November 19, 2007), the participants reviewed more problem-solving activities in order to design/adapt an activity for implementation in their own classrooms. Although the majority of the meeting was spent designing the lesson, Cathy was able to express some beliefs, comments, and curiosity. First, she suggested that these activities could be given as homework and then the next day in class the students could discuss their solutions and strategies for solving them. (This statement does indicate that Cathy was thinking about how to use these activities; however, for this

study, the activities were to be used by the whole class during a mathematics lesson.) During the development of the problem-solving activity for implementation, Cathy suggested adding a step at the end where students must explain their thinking, processes, strategies, and solutions. Consequently the group did develop and add such a question. Lastly, Cathy expressed curiosity about what answers and strategies might emerge as dominant during this implementation; she also wondered if increasingly complex strategies would be used by students of higher grade levels. At this point, Cathy appeared to be excited about implementing the problem-solving activity and curious about what she would observe. In addition, Cathy's focus was clearly on strategy and thinking processes, and she appeared comfortable with implementation of the developed problem-solving activity.

Cathy implemented the activity, "Decoration Delight" on December 7, 2007. First, Cathy ensured that the students understood the task at hand. Second, she indicated that students should focus on explaining their thinking processes and strategies at the end of the lesson. Third, she provided the students with materials they could use, if desired, such as Unifix Cubes, colored pencils, and scrap paper. Fourth, the students were told to work in their table groups of four or five. The students started off working independently but then moved to working as a group and discussing their thinking. Fifth, Cathy walked around the room while the students were working and asked the students about their thinking and what type of strategy they were using and why. By asking these questions of each group, she guided them to discuss their thinking with one another. Lastly, by the end of class, each group came up with a solution, but there was no time for discussion.

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However, Cathy used the beginning of the next day's class to conclude the activity with a whole-group discussion of the students' thinking processes and strategies.

Overall, Cathy's implementation of this first problem-solving activity reflected the beliefs about strategies, justification, and discussion she had stated during PLC meeting 1 and meeting 2. Her focus on the students' thinking processes and strategies was very clear in the questions she asked the students while they were working as well as in the sharing she had them do as a whole group the next day. Those two actions promoted discussion and encouraged the students to justify their solutions.

After implementation of the first problem-solving activity, we met for the third PLC meeting (January 7, 2008) where the participants discussed how they had implemented the activity and what observations they had made of their students. Cathy listened to the other participants share and then commented on her own implementation. She explained that she had used a very hands-off approach during implementation and described her students' different strategies. Her only response to the other participants' explanations was that she thought her students had used more complex strategies. Cathy did not reflect or comment on anything that she might do differently the next time.

Section 2 (January-February). Cathy implemented a second problem-solving activity, "Counting Squares," which she had chosen and adapted, on January 24, 2008. The students were presented with a four-row stair-step triangle of squares. They were asked to count the number of squares they saw in that pyramid. Then they were asked to add another row to the figure and to count the squares once again and to continue for multiple iterations, looking for patterns. Cathy simply introduced the activity by reading

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the problem and telling the students that they could interpret "square" as they deemed fit. The students all ended up with the same interpretation: a square of any size could be counted. She provided the students with grid paper to use if they wanted. The students again worked in groups and engaged in ample discussion. Cathy walked around to each group again, asking the students questions about their answers, their method for keeping track of the squares, and if they were seeing any patterns. At the end of class, Cathy reassembled the students as one group to discuss their solutions and discoveries. However, this discussion was not as in-depth as the discussion from the first activity. Overall, however, Cathy had a very similar implementation process for the second lesson as the first..

During the fourth PLC meeting, held on February 11, 2008, the participants again shared their implementation processes and observations. Cathy did not reveal any additional information about her beliefs. She shared her actions and her observations with respect to her problem-solving activity. She did not reflect about her implementation or respond to the other participants' comments.

Section 3 (March-April). Cathy implemented the last problem-solving activity, "Which Box?" on March 13, 2008. In this activity, the students needed to figure out how marbles were arranged in three boxes by looking into one box only. Cathy began by reading the problem and explaining that a "yes" or "no" answer would not be sufficient. The students then began to work in groups, but they had many questions about the "realness" of this problem and its solvability. As a result, Cathy redirected the class by providing a hint. The students then worked again in groups for a brief period until Cathy

pulled all the students them all together as a whole class. The students who had figured

out the problem shared their strategies and solutions. To close, Cathy posed some

extensions to this activity that the class discussed; she also asked them what

mathematical concepts were used since they had initially doubted the "realness" (i.e.,

applicability to real life) of this activity. In sum, Cathy's approach to this activity was a

little different than in the previous two activities. She readjusted her implementation

based on the students' responses, questions, and apparent confusion.

The fifth and final PLC meeting took place on April 21, 2008 and again the

participants shared their implementation processes and observations. Cathy simply

described what she had done and provided two comments on her implementation. First,

she stated that she realized that sometimes the students might need a little more guidance,

based on the activity and hence she pulled the students together in the middle of the

activity to clear up their misunderstandings. Second, she commented that she thought the

discussion that the students had had at the end of this activity, which was significantly

longer than the whole-group discussions of the other two activities, had been very

successful.

In summary, at this point in the study, after implementing the problem-solving

activities and participating in the PLC meetings, Cathy's stated beliefs and observed

actions supported one another. Her stated beliefs about problem-solving activities

emerged during the first PLC meeting and remained the same throughout the study. She

did express one discovery: that sometimes students may need more guidance than

anticipated, depending on the activity. If that is the case, she advised providing that guidance then and there, rather than just letting them go to work in complete confusion.

Post PLC. I made my final observation of one of Cathy's mathematics lesson on April 17, 2008. Cathy's actions during this lesson were consistent with several of her pre-stated beliefs. First, she taught the mathematical concept, permutations and combinations, in several ways. Cathy had originally taught the students how to find the answer by using formulas, which they went over during the homework review. However, during this lesson, Cathy introduced Pascal's Triangle and how it could be used to solve for combinations and permutations. Second, she incorporated a hands-on activity where students could manipulate Pascal's Triangle. Third, Cathy provided the students with time to practice what they were learning by giving them real-life examples of finding permutations and combinations. Lastly, the lesson plan format that Cathy had spoken about during the pre-interview was still present, but the parts now seemed to flow into each other, rather than being separate sections.

While her stated beliefs supported her actions, Cathy added a step I had not observed in her other lessons: she connected what the students were doing to a prior activity, "Decoration Delight," the first problem-solving activity. When the students were given that activity, they had not yet learned about permutations and combinations and so had applied their own strategies, rather than using the formula they had just learned. During PLC meeting 1, Cathy did state how problem-solving activities could be used as an introduction to a unit. Cathy did not use that activity as an introduction; however, she referred back to it while teaching the concept. Perhaps in the future Cathy might use

"Decoration Delight" as an introduction to her unit on permutations and combinations. In sum, I observed the beliefs Cathy had stated during the pre-interview in all the classes I visited, from the first to the last. However, I saw this critical connection of students' current and past learnings for the first time in the last lesson.

I gathered Cathy's final stated beliefs and knowledge about teaching and learning mathematics from her post interview on May 19, 2008. One was exactly the same, pre and post: lessons should involve hands-on activities. Cathy's belief about teaching different strategies was somewhat modified: she now believed that students should have the opportunity to share the strategies they use. Her beliefs about problem solving had also evolved: she now stated that such activities should be incorporated into lessons and involve a multi-step processes, and that, in addition to the textbook, other resources should be used as a source of activities.

With respect to instructional practices, Cathy stated that she could spend less time with the pacing guides and the SOLs as she was familiar with them now; therefore she had more time to explore resources other than the textbook to create more hands-on and real-life lessons/activities. In addition, Cathy commented that she had started to use the feedback and misunderstandings of the students as input to her planning, and she also wanted to do more collaborative planning with other teachers. However, although Cathy made these points, she also still stressed that her main focus was completing the curriculum.

Results for Sub-Questions A and B of Research Question #1

In this section I provide responses to sub-questions A and B, stating how Cathy's beliefs and instructional practices changed throughout the study.

How did Cathy's beliefs change? It is clear that there was minimal evolution in Cathy's beliefs during this study. Cathy stated several beliefs in the beginning of the study that she restated again at the end: (a) Students should be taught multiple strategies to solve/understand mathematics. (b) Lessons should incorporate hands-on activities. And, (c) students should have opportunities to practice what they are learning during lessons. I observed these beliefs reflected in her practices at the beginning and at the end of the study. Although Cathy did not state a belief about connecting previously learned and newly learned mathematical concepts either at the beginning or the end of the study, she made this connection during two observed lessons.

I noticed the most significant changes in Cathy's beliefs about problem solving. In the pre-interview, Cathy stated that problem-solving activities involved students reading a word problem and solving it using a strategy they have already learned. During the first PLC meeting Cathy talked about two beliefs: (a) Open-ended activities are better than one-step word problems because they promote discourse and justification of a solution. And, (b) the focus of problem solving should be on student strategies and thinking processes. These beliefs, then, were evident very early in the study—at the first PLC—and remained the same throughout the study. On the other hand, during the pre-interview Cathy said that problem-solving activities should be taught at the end of a lesson. However, during the post interview, she stated that problem-solving activities

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should be incorporated into mathematics lessons and could also be used to introduce concepts. Clearly, Cathy's beliefs about the timing of problem-solving activities had changed.

Lastly, in the beginning of the study, Cathy believed that pacing guides and SOLs should be the determining factors in planning lessons. By the end of the study, she still believed that they were important; however, she thought other resources should also be used to make lessons more hands-on. Additionally, she stated that she used student feedback and misunderstandings to plan as well.

How did Cathy's instructional practices change? During the study, Cathy's instructional practices changed only a little both in her mathematics lessons and in her implementation of problem-solving activities. In the beginning of the study, Cathy did use a hands-on game at the end of the class as a review. During the last class that I observed, Cathy used a hands-on activity during the main lesson. In that same lesson, Cathy made connections for the students between what they were currently learning and what they had learned before. This type of association had not been established during the lessons I had observed at the beginning of the study. Finally, the parts of her lesson—homework review, warm-up, lesson, and practice—were connected to each other, rather than being four distinctly separate parts.

The implementation of Cathy's first two problem-solving activities was almost identical. However, the third problem-solving activity took on a different look: Cathy began in the same way, but once she discovered that the students were confused and had many questions, she pulled them back together as a class to provide some clarifications.

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She then let the students work for a little bit, but then held a concluding whole-class discussion that was longer than the discussions during the first two activities. At this point, Cathy provided connections and extensions, which had not been offered in the earlier activities. Overall, as a result of the year-long professional learning community, Cathy's instructional practices changed in some ways.

Results for Research Question #2

The second research question (What influences these teachers' decision making throughout the year?) was answered by gathering information during the year via pre- and post interviews and using comments, reflections, and questions from the five PLC meetings. From the data analysis, I was able to distinguish three influences/explanations for Cathy: (a) knowledge about teaching and learning mathematics, (b) willingness to reflect upon and change her own practices, and (c) ability to respond to her students.

During a discussion about problem-solving activities in PLC meeting 2, Cathy mentioned how she had taken a mathematics methods class where her teacher focused a lot on problem solving and hands-on activities. The teacher gave the class a problem every week to solve, and then during the next class they would discuss the various methods each person used to solve it. As a result, Cathy came into this study with knowledge about problem-solving activities and an understanding that there are many different ways to solve the same problem. Cathy appeared to use this knowledge and experience while implementing her problem-solving activities.

While Cathy participated in the PLC meetings, she mostly spoke about her beliefs and shared her implementation methods during the three problem-solving activities. She

did not reflect on her actions during implementation or comment on how she could use the other participants' ideas in her classroom. Cathy appeared to be satisfied with her implementations and did not feel a need to change.

Lastly, I observed that Cathy responded to her students' actions and questions during lessons. For example, she was able to spontaneously change her instructional plan for the day to meet students' needs. In conclusion, these three aspects about Cathy seemed to influence Cathy's beliefs and instructional practices during the study.

Similarities and Differences Between Emma and Cathy

The one similarity between both Emma and Cathy was the evolution of their beliefs and instructional practices throughout the study. Emma's changes, however, were much more significant than Cathy's. This difference in degree can be explained by several factors. First, Emma seemed more open to change than Cathy. Emma was very reflective about her implementation of mathematics lessons, listened to and valued other teachers' beliefs and instructional practices, and took what she learned back to the classroom to try during another lesson. Cathy did not seem as receptive to change, perhaps because she felt that the way she implemented her lessons was already effective. Second, Emma began this study with less knowledge and understanding of problem solving than Cathy, therefore, perhaps she had more room to grow. As she accumulated learnings, her beliefs and instructional practices evolved to include this new knowledge.

Third, while both Cathy and Emma stated at the beginning of the study that curriculum was the main influence on how they planned lessons, Emma moved away from this sole influence to include other resources. By the end of the study, she was

familiar with the curriculum and strove to make her lessons more interactive. Cathy, however, remained curriculum-driven. Lastly, both participants did incorporate more problem solving into their classrooms by the end of the year; however, Cathy did so only with her higher achievement level math class (sixth-grade students learning seventh-grade math), because she believed that the lower ability students would have a difficult time with additional problem solving and they needed to spend their time mastering basic math facts. Emma implemented problem-solving activities with both of her classes, sixth-grade students doing sixth-grade level mathematics. Overall, both participants' beliefs and instructional practices evolved throughout the study, with Emma's undergoing the most change.

Results for Research Question #3

My role throughout this study was two-fold: researcher and teacher leader. As the teacher leader, I had three mains functions: (a) facilitating all of the PLC meetings, (b) supporting the teachers while they created problem-solving activities and implemented them in the classroom, and (c) participating fully in the PLC meetings. To document my decisions and actions throughout, I kept a journal, and I have explained many of them in Chapter 4 as part of my description of events. However, to provide a complete answer to the third research question, which addresses the decision-making influences of a teacher leader, I deemed it important to discuss the details of each function as it relates to the three phases of data analysis: (a) pre-PLC, (b) implementation of a problem-solving based PLC and problem-solving lessons, and (c) post PLC.

Pre-PLC

Before beginning the PLC meetings, I conducted a pre-interview with each participant and observed them teaching two mathematics lessons each. The main purpose of the pre-interview and these two observations for me as researcher was to gather information about each participant's beliefs, knowledge, and instructional practices. However, the data provided me, as teacher leader, with information about the participants that I could use in planning the first PLC meeting. From the pre-interviews of the participants, I discovered that both lacked knowledge about the current views of problem solving in mathematics.

Implementation of Problem-Solving Based PLC and Problem-Solving Lessons

Here I will discuss the various influences that affected my decision-making processes and actions during all five PLC meetings and all three problem-solving lesson observations. I will present the results as they occurred, divided into the three subsections I established for this phase of the data analysis.

Section 1 (October-January). As a result of what I discovered during the pre-interview, I decided to design the first PLC meeting as an information session, sharing the following information: (a) traditional versus reform views of problem solving as noted in the research as well as from the NCTM *Standards* (2001), (b) the effects of incorporating problem-solving activities as noted in current research, (c) personal experiences taken from my seven-years of teaching experience that are related to problem solving, and (d) examples of problem-solving activities.

I began with a PowerPoint presentation that I had created. I next facilitated a discussion on problem-solving activities, based on a handout with several examples that I had distributed. I asked probing questions, commenting on their responses and providing further feedback. Next, as mentioned in Chapter 4, I summarized and provided the participants with a recent article from the September 2007 issue of the journal *Teaching Children Mathematics*. This article described how five mathematics teachers from different grade levels implemented the same problem-solving activity and what they observed from their students. I summarized the main points of the article and suggested they read it. I concluded by indicating that next time we would look at more problem-solving activities in order to create one to implement in the classroom.

In summary, during the first PLC meeting, I did most of the talking because I was providing information and examples of activities. The participants were the biggest decision-making influence on my actions during the PLC meeting. By providing them with information and activities on problem solving, I unintentionally began scaffolding them.

My planning of the second PLC meeting was influenced by one of the goals of the PLC: implementing problem-solving activities. I provided the participants with many examples of problem-solving activities from the book *Children Are Mathematical Problem Solvers* (Sakshaug et al., 2002). I allowed time for the participants to look through these activities and decide if they thought implementing one of them was feasible. On their own, the participants agreed on "Decoration Delight." After they had made their decision, I facilitated a brief discussion about implementing the activity. I

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kept the discussion short because I did not want to tell the participants how to implement

the activity; I wanted to observe how each participant would decide on her own. I

covered general guidelines like implementing the activity during class time and having

the students work in pairs or small groups. In addition, I gave the participants a graphic

organizer to record their observations of the students while they worked on the problem-

solving activity. By doing so, I implicitly guided them towards focusing on student

learning. Lastly, without any prompting from me, Cathy suggested requiring the students

to write a letter explaining how they had solved the problem

In sum, during the second meeting, my role was not as dominant as in the first.

Here I provided the participants with activities, but then let them determine and design

the activity that would be used. My guidance during this meeting continued the

unintentional scaffolding process. In the first meeting I gave them information/taught

them and directed them. Then, in the second meeting I supported them while they chose

a problem-solving activity from the provided materials, listened while they made

adjustments to the activity, and unobtrusively suggested a few minor implementation

procedures.

During this time period I observed the participants' implementation of the

problem-solving activity. My goal, as researcher, was to gather information about their

instructional styles. This information did not influence my decisions about planning the

third PLC meeting, but rather provided me with possible comments to share during the

discussion time.

The focus of the third PLC meeting, to discuss the implementation process and observations during the problem-solving activity, had already been established at the end of the second PLC meeting. As planned, we all shared; by sharing my implementation process and observations, I also became a participant. In addition, since I had observed the participants during implementation, I asked questions and made comments about what had occurred during their lessons to add to what they were sharing. The meeting concluded with the participants deciding to choose their own problem-solving activity to implement.

In sum, my main role during the third meeting was participant. I did facilitate some discussion, but mostly I shared my own experiences, listened to the participants, and made comments or asked questions when I thought it was appropriate. The unintentional scaffolding process continued since the participants did most of the sharing and it was up to each of them, independently, to select a new problem-solving activity to implement.

Section 2 (January-February). This section included an observation of the second problem-solving activity implemented by each participant and the fourth PLC meeting. Both the observation and the PLC meeting were quite similar to the previous ones, respectively. I again used the observation to gather information about each participant's instructional practices while implementing the second problem-solving activity. I used this information, as before, to enhance discussions, if needed.

The purpose of the fourth PLC meeting was to discuss each participant's implementation of the second problem-solving activity. As teacher leader, I took on a

facilitator role to gently guide the discussion, which ultimately was participant-lead. I felt that if the participants controlled the meetings the experience would be more beneficial and meaningful for them, more so than if I had them hew to an agenda I had planned beforehand.

Section 3 (March-April). I observed each participant's implementation of a third problem-solving activity and the focus of the fifth PLC meeting was again on discussion of their processes and observations. The conduct of the meeting and my role were similar to those of the previous meeting; the only difference was the conclusion. Every PLC group at the research site is required to share its accomplishments at the beginning of the following school year. We decided that our sharing should include a compilation of all of the problem-solving activities for the other teachers to use as a resource. Therefore, we made an electronic document containing the problem-solving activities they had all implemented, their lesson plans, suggestions for implementation, possible modifications for all grade levels from kindergarten through sixth grade, and extensions for each activity to further challenge students. The following school year, the group would present this document as well as a brief summary of what they had achieved during the year to the entire staff. Overall, the entire group had a sense of accomplishment and of having new knowledge they could use in their mathematics classroom. I attribute this success to the teachers' empowerment: ultimately they organized and controlled the direction of the meetings.

In conclusion, this chapter provided answers to the three research questions that guided the direction of this study. The answer to research question 1 indicated that the

beliefs, knowledge, and instructional practices of both participants changed, Emma's more so than Cathy's. The answer to research question 2 explored the decision-making influences of both participants. Lastly, the answer to research question 3 covered the factors that influenced my, that is, the teacher leader's, decision-making processes. In addition, from analyzing my journal entries, I discovered how my role had changed throughout the study and affected the participants. In the next chapter, I will discuss the conclusions I drew from my findings.

CHAPTER 6: DISCUSSION

Problem solving in mathematics has been a central focus for scholars and reformers over the last twenty-five years (Perrenet & Taconis, 2009). As a result, mathematics teaching and learning have been undergoing major reforms. Teachers are considered to be the most influential agents in implementing these reforms through the curriculum. Specifically, researchers have studied teacher's beliefs and knowledge as well as the staff development programs they participate in, to determine which aspects affect change in teachers the most (Levine, 2011).

This study followed two sixth-grade teachers as they participated in a year-long professional learning community focused on incorporating problem-solving activities into the mathematics classroom. These three research questions guided the study:

1. How do two grade six teachers respond to a problem-solving based professional learning community (PLC)?

   a. Do these teachers' beliefs and knowledge change, if so, in what ways?

   b. Do these teachers' instructional practices change, if so, in what ways?

2. What influences these teachers' decision making throughout the year?

3. What are the decision-making practices of a teacher leader?

In analyzing the results from the study, I came to two overall conclusions: (a) The two participants' beliefs, knowledge, and instructional practices in regards to

mathematics teaching and learning changed during the year-long PLC focused on incorporating problem solving into the mathematics classroom. And, (b) the role of the teacher leader matters in facilitating teacher change. In this chapter I will discuss the two conclusions and their relationship to current research.

Conclusion 1: The Participants Changed

Two main themes emerged from my conclusion that the two participants' beliefs, knowledge, and instructional practices had changed.   The first is that a professional learning community can support change in the beliefs, knowledge, and instructional practices of teachers so that they become more aligned with current mathematics directives. The PLC, however, must include particular components to help the teacher change. These components, along with how schools can incorporate such a PLC, will be discussed below. The second theme is that the changes in mathematics teachers' beliefs, knowledge, and instructional practices are affected by various characteristics, both personal and contextual. Consequently, one teacher's transformation will be different from another's even when they participate in the same professional development endeavor. Implications for schools of education, professional development organizations, schools and districts, and research will be considered.

Theme 1: Effective Aspects of a Professional Learning Community

Many scholars and reformers have proposed collaborative teacher communities as a means of improving teaching and catalyzing teacher change (Levine, 2011). Currently the terminology for such a practice includes *teacher professional community*, *professional learning communities*, *inquiry communities*, *instructional communities of*

practices, and so on (Levine, 2010). In addition, the components involved in these different teacher collaborative communities vary as well. I used the term *professional learning community* (PLC) to refer to the collaborative teacher community established at the research site.

Earlier research on effective professional development components (Ambrose, 2001, 2004; Artzt, 1999; Bright & Vacc, 1994; Chapman, 1999; Chauvot & Turner, 1995; Crespo, 2003; Hojnacki & Grover, 1992; Lubinski, 1993; McGatha & Sheffield, 2006; Steinberg et al., 1994; Vacc & Bright, 1999; Vacc et al., 1998) lead to the design of the PLC in this study. The previous research focused on one or two effective components; this study combined these research-supported effective components into one PLC as well as others that I thought would be effective based on my experience. The PLC structure used in this study supported the transformations that both participants experienced in their beliefs, knowledge, and/or instructional practices with regards to mathematics teaching and learning. This suggests that together the components in this PLC were effective in supporting teacher change.

The components of the PLC were: (a) information sessions focused on content-specific knowledge (incorporating problem solving into the mathematics classroom), (b) active learning experiences, (c) discussions amongst and collaboration with colleagues, (d) focus on student thinking, (e) opportunities for teacher reflections, and (f) teacher involvement in the development and design of the problem-solving activities. Since the PLC was conducted for an entire school year, the participants had multiple chances to experience all of these components. No other studies have combined all of these

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components into a single PLC (Ambrose, 2001, 2004; Artzt, 1999; Bright & Vacc, 1994; Chapman, 1999; Chauvot & Turner, 1995; Crespo, 2003; Hojnacki & Grover, 1992; Lubinski, 1993; McGatha & Sheffield, 2006; Steinberg et al., 1994; Vacc & Bright, 1999; Vacc et al., 1998). However, research has shown that in some cases, PLCs have been successful using only one or two of the components.

Developing teachers' pedagogical content knowledge is extremely important when attempting to modify these teachers' beliefs and instructional practices (Ball, 1990; Ma, 1999). Since recommendations on best practice in teaching and learning of mathematics have been going through tremendous change, to be effective, teachers need to learn what these new practices are and how to implement them in their classrooms (Garet, Porter, Desimone, Birman, & Yoon, 2001). Simply distributing the reform curriculum and expecting the teachers to change their teaching will not work (Drake & Sherin, 2006). Rather, teachers' beliefs and instructional practices change as a result of particular interactions between teachers and curricular materials around specific content knowledge or instructional practices (Drake & Sherin, 2006; Desimone, Porter, Garet, Yoon, & Birman, 2002).

This study's specific focus on content knowledge centered on incorporating problem solving into the mathematics classroom. Here, the participants were exposed to information on teaching problem-solving through mini-information sessions during the early PLC meetings. In addition, participants explored particular curricular materials and then discussed them with colleagues during the meetings. Results of this study indicate

this component of the PLC was effective in fostering teacher change. This finding supports the results of a previously mentioned study (Hojnacki & Grover, 1992).

Further, other researchers concluded that when teachers are made aware of reform instructional practices, like incorporating problem solving, and engage in active learning experiences, the positive effects on the teachers' instruction increased (Ambrose 2004; Artzt, 1999; Chauvot & Turner, 1995; Crespo, 2003; Desimone et al., 2002; Lubinski, 1993; McGatha & Sheffield, 2006; Vacc & Bright, 1999). According to these researchers, active learning experiences include teachers working one-on-one or in small groups with students in their classrooms as well as engaging in the problem-solving tasks themselves. In the present study, the participants were encouraged to talk with their students while the students work on problem-solving activities. Additionally, during PLC meetings the participants examined and worked through certain problem-solving activities that they would then use in their classrooms. By doing so this added yet another effective component to this study's PLC, which was consistent with the findings of previous researchers (Ambrose 2004; Artzt, 1999; Chauvot & Turner, 1995; Crespo, 2003; Desimone et al., 2002; Lubinski, 1993; McGatha & Sheffield, 2006; Vacc & Bright, 1999). However, the majority of the previous research was conducted with pre-service teachers engaging in active learning experiences both at their student teaching sites and within their mathematics methods courses. The present study adds a new facet to the research on this topic: these participants were in-service teachers working with their current students and engaging in problem-solving tasks with their colleagues during the PLC meetings at the school.

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Participants noted a third effective component of this study's PLC: the opportunity to discuss and collaborate with colleagues throughout the entire PLC process. Discussion is an integral piece of PLCs (McLaughlin & Talbert, 2006) and teacher collaboration provides support to teachers while they are trying to incorporate a new instructional practice (Park, Oliver, Johnson, Graham, & Oppong, 2007). Discussion and collaboration have proved to be effective ways for teachers to improve practice and advance student learning (McLaughlin & Talbert, 2006; Park et al., 2007). In the present study, the participants discussed what they had learned about incorporating problem solving, their thoughts on and interpretations of the problem-solving activities, misunderstandings about what they were learning, and so on. PLC members were able to collaborate with each other, that is, mathematics teachers at various grade levels. Both participants in this study indicated that they thought collaboration with teachers of various grade levels was effective and different from other professional development endeavors they had experienced in the past. The present study adds to the findings of previously mentioned studies (McLaughlin & Talbert, 2006; Park et al., 2007) showing that these components are effective in improving instructional practices, by adding the specific focus on incorporating problem solving.

Another effective component of a PLC that this study found to be effective was the teacher's focus on student thinking. Such a focus enables a teacher to understand why their students thought about a particular mathematical task as they did (Chamberlain, 2005) and poses a promising avenue for belief change in teachers (Ambrose, 2004). Researchers have found that when teachers work one-on-one or in small groups with

students while they engage in specific mathematical tasks designed to elicit their thinking, the teachers learn how children think and how they learn mathematics (Ambrose, 2004; Chamberlain, 2005, Lubinski, 1993). These researchers further discovered that what the teachers learned fostered their changing beliefs and the new knowledge was then reflected in their instructional practices. In the present study, Emma was a prime example of how focusing on student learning can elicit change. In the beginning of the study, Emma was hesitant to believe that her students could successfully engage in the problem-solving activities presented during the PLC meetings. After Emma implemented the activities and interviewed students while they were working, her beliefs changed. She realized that her students were more than capable of successfully solving the activities and needed little guidance. This finding supports and adds to the previous research.

Teacher reflection has also been proven to be a powerful agent in teacher change and central to the improvement of mathematics teaching (Artzt, 1999; Chapman, 1999; Perrenet & Taconis, 2009; Vacc & Bright, 1999; Warfield, Wood, & Lehman, 2005). Teachers can reflect via written narratives, questionnaires, or oral responses to interviews or in discussions. During the present study, the participants had opportunities to reflect about what they were learning in regards to incorporating problem solving, observations from their students while they were engaged in problem-solving tasks, and their own implementation process of these activities. These reflections took place during PLC discussions as well as during the researcher's interviews of the participants. The effectiveness of the reflection component of the PLC during this study is consistent with

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the findings of previous studies (Artzt, 1999; Chapman, 1999; Perrenet & Taconis, 2009; Vacc & Bright, 1999; Warfield et al., 2005). By looking at in-service teachers, this study adds to the findings as the majority of the previous studies examined pre-service teachers' reflections.

The final component that proved effective in this study, based on participant feedback, was offering opportunities for teacher involvement in the development and design of the problem-solving activities and the events during PLC meetings. There has been very little research on this topic; however, researchers have found that professional learning programs are especially productive when teachers' input is used to create instructional activities and shape the program's focus (Ball, 1995; Hojnacki & Grover, 1992). Further, providing such opportunities gives the teachers a sense of ownership, which leads to increased teacher change in beliefs, knowledge, and instructional practices (Ball, 1995; Hojnacki & Grover, 1992). The findings of this study add to the small body of research in this area.

In summary, the present study found six effective components of a PLC that supported teacher change in beliefs, knowledge, and instructional practices in regards to mathematics teaching and learning (most specifically in incorporating problem-solving activities). These components were found effective from the participants' perspectives and all have been supported by previous research. However, no previous studies integrated the six components together. As a result, this study contributes a new avenue for the development of various types of PLCs in schools.

Theme 2: Various Characteristics that Explain Differences in Teacher Change

The main purpose of this study was to explore how teachers responded to a year-long PLC focused on implementing problem solving. Analysis of the data made clear that both participants changed their beliefs, knowledge, and/or instructional practices. An unanticipated finding resulted from these changes: The two participants evolved in different ways. I suggest that certain of the participants' characteristics may explain these differences. There has been very little research on why change differs from one teacher to another. Researchers have focused predominately on how to effectively foster teacher change (Ambrose 2004; Artzt, 1999; Chauvot & Turner, 1995; Crespo, 2003; Desimone et al., 2002; Lubinski, 1993; McGatha & Sheffield, 2006; Vacc & Bright, 1999), but not on how the changes may be different and why. In this section, I will discuss two categories of characteristics (personal and conceptual) that may explain these differences. In addition, available research that supports these findings will be addressed.

Personal characteristics. The present study found some personal characteristics that may account for the differences in the two participants' transformations during the year-long PLC: teaching experience, past learning experiences, ability to reflect on practice, and teacher efficacy. The two participants did not have the same teaching experience: it was Cathy's third year of teaching math; it was Emma's first year of teaching math, although she had taught science during the three previous years. In other words, Cathy had two years of teaching experience in math, whereas Emma had none. However, Emma's beliefs, knowledge, and instructional practices changed overall more than Cathy's. Obara and Sloan (2010) discovered in their study that the less experienced

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teacher was more open to trying new teaching materials and methods than the more experienced teacher and, as a result, changed more. They speculated that the less experienced teacher had not been teaching long enough to settle into a particular way of teaching mathematics and was, therefore, more open to various suggestions. This may have been the case with Emma and Cathy as well.

In addition to teaching experiences, past learning experiences, such as coursework and teacher training, may also help explain why Emma changed more than Cathy. One of Cathy's mathematics methods classes during her graduate program focused specifically on problem solving. As a result, Cathy was more familiar with implementing problem solving, which was apparent during her pre-interview and observations. Emma, on the other hand, had no prior training related to problem solving. Since Cathy already had some of the target instructional practices in place, she actually had less scope for change than Emma. In addition, Cathy took on the role of math lead in the school, which required her to attend a monthly class centered on learning new trends in mathematics teaching and learning. Again Cathy had more beginning knowledge, which could account for the smaller change.

Reflection was an integral part in this study's PLC. Research (Artzt, 1999; Chapman, 1999; Perrenet & Taconis, 2009; Vacc & Bright, 1999; Warfield et al., 2005), as mentioned in the previous section, has proven that teacher reflection is a powerful agent in teacher change. Analysis of Emma's participation during PLC meetings shows she was more willing to reflect upon her process of implementing problem-solving activities than was Cathy. Perrenet and Taconis (2009) demonstrated in their study that

teachers who participate in reflection are more likely to change their beliefs, knowledge, and instructional practices to a higher degree. Given Emma's greater participation in the teacher reflection process, it is not unreasonable to conclude that she probably benefited more from it than did Cathy. This finding may be part of the reason why Emma showed a larger change than Cathy.

The teacher efficacy beliefs that emerged during the present study may also help explain the differences. *Efficacy beliefs* refer to how a teacher perceives his or her ability to plan and execute actions to achieve a goal (Charalambous & Philippou, 2010). Researchers have paid particular attention to the personal characteristics and capacities that could affect curriculum reform implementations (Charalambous & Philippou, 2010). Through my observations of both participants, in the classroom and in the PLCs, I was able to discern their teacher efficacy beliefs. Cathy appeared to be confident in implementing problem-solving activities as well as responding to her students' actions during such activities (high efficacy beliefs). As a result, she was willing to incorporate this instructional approach. Emma, on the other hand, expressed in her interview and PLC discussions that she was not as comfortable with these activities (low efficacy belief); however, she was willing to take risks in an attempt to make her instruction more effective, showing that her efficacy beliefs were also evolving. I infer that, since Cathy was already confident in her abilities, she did not feel the need to change as much as Emma did. Because Emma's willingness to take risks trumped her initial low efficacy beliefs, she implemented the problem-solving activities, causing an evolution in her instructional practices and, ultimately, an increase in her efficacy beliefs. Charalambous

and Philippou (2010) found similar results in their study, conducted in Cyprus. The present study extends their finding to the United States.

Contextual characteristics. The present study found that contextual as well as personal characteristics accounted for the differences between the two participants' changes in beliefs, knowledge, and instructional practices. These contextual characteristics include the teacher's task and impact concerns. Task concerns relate to the daily duties of a teacher's job, such as time constraints, the pressure to cover the curriculum, and accountability for students' testing scores (Charalambous & Philippou, 2010).

Researchers have found that due to concerns about covering the curriculum in the allotted time coupled with worries about students' performance on standardized assessments, teachers are less likely to implement curriculum reforms, choosing instead to use traditional methods of delivering instruction, like drill and practice (Charalambous & Philippou, 2010; Obara & Sloan, 2010). Cathy expressed these concerns during her post interview, explaining that she saw the value in including problem-solving activities in instruction, but felt they were time consuming. She stated that she had a lengthy curriculum to cover in a short period to prepare her students for the end-of-the-year standardized tests, allowing little time for problem-solving activities. In the beginning of this study, Emma had had similar concerns, but by the end of the study, she had seen that problem-solving activities were not simply entertaining diversions from the curriculum; they could actually be used to teach required math concepts more effectively than the traditional methods. As a result, Emma's task concerns had diminished by the end of the

study and her comments indicated a likeliness to continue implementing a reform curriculum. These findings were consistent with the two research studies mentioned above.

Teacher change can also be influenced by another contextual characteristic: impact concerns. Impact concerns are around the possible negative consequences of the change on student learning (Charalambous & Philippou, 2010). I found only one such concern in this study, which Cathy expressed, related to the students' capacity to engage in the higher order thinking tasks found in problem-solving activities. Obara and Sloan (2010) found that teachers' under-estimation of their students' abilities could keep them from implementing reform curriculum. Cathy expressed such a concern and consequently only incorporated problem-solving activities with her higher achieving math students (sixth graders learning seventh-grade math). She did not feel that her lower achieving mathematics class (on-grade-level sixth graders) would be capable of succeeding in the problem-solving tasks because, for example, they still have difficulties memorizing math facts. Emma, on the other hand, apparently did not have this impact concern as she incorporated problem-solving activities into both of her on-grade level, sixth-grade math classes.

In summary, the present study found that dissimilarities in the participants' transformations could be attributed to differing personal and contextual characteristics. As stated earlier, there is very little research in this area. Previous research focused primarily on promoting teacher change. Therefore, the findings of this study have implication for future research in regards to teacher change.

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Conclusion 2: The Role of the Teacher Leader Matters

Throughout the entire study, I, as the teacher leader, kept a journal to reflect influences of my decisions in planning and running the PLC meetings. After analyzing this data, I concluded that my role as teacher leader contributed to fostering the change in my participants' beliefs, knowledge, and/or instructional practices. My role as teacher leader comprised seven actions: (a) I planned thoughtful agendas for the PLC meetings, based on information gathered from the participants. (b) I provided information about current reform beliefs in mathematics problem solving as well as examples of problem-solving activities. (c) I structured and facilitated discussions during the PLC meetings. (d) I observed the participants' problem-solving lessons. (e) I scaffolded the participants' implementation of problem-solving activities in the classroom. (f) I helped the participants make connections during discussions. And, (g) I guided the participants in recognizing the changes they were undergoing. These actions that I performed as teacher leader contributed to the changes that occurred in my participants' beliefs, knowledge, and instructional practices during this study.

There is a paucity of research exploring the relationship in PLCs between participant evolution and the teacher leaders. Kingsley (2012) explored the possibility that the key to strengthening PLCs is the teacher leaders. In her five-year case study of one school district, selected teachers participated in a year-long training program to prepare them to be leaders of their schools' PLC. Kingsley (2012) provided a very brief description of the aspects of this training program. For example, she explained "teachers

experimented with tools for developing agendas and the basics of facilitating" (Kingsley, 2012, p. 25).

After training, during the following school year, the teachers lead PLCs in their respective schools. Kingsley (2012) concluded that when teachers are trained to be effective teacher leaders in PLCs, the results are profound. Kingsley, however, based teacher-leader effectiveness on the students' academic progress. In the present study, I examined teacher-leader's roles in relationship to their changing beliefs, knowledge, and instructional practices. While Kingsley's study (2012) provided guidance on training teacher leaders, it did not examine how the teacher leader affects the teachers. The finding of the present study that the role of a teacher leader contributes to teacher change, opens up a new area of exploration for researchers.

Implications for Practice

Implications for practice from this study include the design and implementation of professional learning programs in schools and districts. According to Levine (2011), scholars and reformers proposals for collaborative teacher communities as a means for improving teaching and learning have resulted, over the past ten years, in schools and districts implementing such communities. In addition, the focus of scholars and reformers over the last twenty-five years on problem solving in mathematics has led to ongoing major reform in mathematics teaching and learning (Perrenet & Taconis, 2009). For this reform to benefit children, in-service teachers must have an opportunity to learn these new reform curricula and ideas. And, much training has been delivered in schools across the country, but its effectiveness requires evaluation. The present study

implemented a PLC focused on incorporating problem solving into the mathematics classroom and explored the effectiveness of this PLC on teacher change. Six components of the PLC were found to be effective. Various researchers had previously also found these components to be effective, but never in combination. I recommend that these components be considered as collaborative teacher communities are developed, as discussed below.

First, when creating the desired collaborative teaching community, schools should ensure that during their meetings, teachers are presented with all the content specific knowledge they need. The focus for the community could be one of any number of topics arising from recent reform movements or areas that teachers deem important to improving student performance. The school can bring in experts on the chosen topics or the community of teachers can find resources that will enable them to learn together.

Next, the collaborative learning community should have opportunities to participate in active learning experiences revolving around the topic of focus. For in-service teachers, schools can provide lessons in the chosen topic or teachers can be asked to develop instructional activities to try in their classrooms. During classroom implementation, teachers should focus on student thinking by working one-on-one or in small groups of students and conducting informal interviews to learn more about how their students learn mathematics. Then, after implementation and after teachers have amassed information on their students' learning modes, teachers should have opportunities to meet with their collaborative team to discuss their observations and thoughts. Additionally, schools should provide avenues for teacher reflections, either

during discussions in the collaborative learning community meetings or through written responses via a journal, for example, or both.

Lastly, professional development has been proven to be more effective when teachers are involved in the development and design of their own collaborative learning experience. Involvement includes being in charge of the agenda and determining the focus, nature, and types of experiences. Teachers can be responsible for choosing the topic, researching the topic, and designing meaningful tasks to bring back to their practice. In conclusion, by incorporating the six effective components of professional development endeavors described in the present study, schools are providing their teachers with experiences capable of realigning their beliefs, knowledge, and instructional strategies with current reforms. The ultimate result is one which will benefit our entire society: improving student learning.

In addition to implementing these six effective components, schools should also carefully select the teacher leader in the PLC. This study differs from those that came before in that a knowledgeable teacher leader guided the PLC meetings. To ensure a successful outcome, I recommend that schools use the seven teacher-leader actions discussed above to train prospective PLC leaders.

Implications for Future Research

I suggest below several areas of future research that would benefit the teaching and learning of mathematics as well as the study of teacher change.

First, this study did find that mathematics teachers can change their beliefs, knowledge, and instructional practices while involved in a professional learning

community. This study also considered how teachers change to align more with reform directives specifically incorporating problem solving into the mathematics classroom. A small body of previous research has produced similar results, primarily with pre-service teachers. Research should expand to include in-service teachers and how they change to meet evolving practices in mathematics teaching and learning.

Second, while this study demonstrated that participation in a PLC supported teacher change, the results are based on only two sixth-grade teachers. I purposefully used a small sample so that I could examine the teachers' responses to the PLC in depth. To explore whether these results are generalizable to a larger sample, the study should be replicated with a larger pool of teachers from various grade levels and with varied lengths of teaching experience.

Third, this study spanned an entire school year and reported changes apparent in the teachers' beliefs, knowledge, and instructional practices at the end of the year. It would be fruitful to follow the teachers for another year after they completed the PLC. Monitoring the teachers over a longer period of time would allow researchers to determine if the changes were sustained. During the additional year, if the changes were sustained, researchers could endeavor to identify what factors contributed to this persistence; if the teachers reverted back to old practices, researchers could attempt to determine the causes.

Fourth, this study yielded unanticipated findings about why teacher change may differ among teachers in the same professional learning community. Little research has been done on this topic; researchers tend to focus more on whether there was change.

This study found that teachers' varying personal and contextual characteristics can account for differences in teacher change. Future studies could establish broad categories of characteristics and then determine what type and level of change is associated with each. Such insight might help researchers to develop experiences for teachers that would produce even more change to their beliefs, knowledge, and instruction practices. These studies need not be limited to the field of mathematics education, but could include other critical disciplines like reading education.

Lastly, the present study found that the teacher leader's role is significant in facilitating teacher change. This role should be further explored. Research could endeavor to document the different roles of teacher leaders and their varied effects on participating teachers. In the present study I was the only teacher leader studied, the PLC was focused solely on incorporating problem solving into the mathematics classroom, and teachers involved were from an elementary school. Perhaps future research could include a larger sample from various schools including PLCs focused on a range of subjects and grade levels. The larger sample size could be handled by using surveys and interviews.

Limitations

It is important to note that I was, in fact, a teacher at the research site and a colleague of the participants. This relationship may have limited the results. The participants may have felt pressure to incorporate certain instructional practices to avoid criticism. And, as previously noted, the study did span only one school year. Extending the study another year could reveal if the teachers' changes were sustained and, if so,

proving the longevity of the PLC's influence. Finally, the study included only two

teachers, thus limiting the extent to which the results can be generalized to other

mathematics teachers.

Final Thoughts

The need for this study arose from NCTM's (2000) and NRC's (2001, 2005) call

for a more problem solving, sense-making instructional mode in mathematics that moves

away from the mere transference of isolated skills and procedures. However, this new

vision of school mathematics cannot be realized without radical change in teachers'

beliefs, knowledge, and instructional practices. Consequently, I chose a professional

learning community as a means to introduce and support change, a method proposed

recently by scholars and reformers (Levine, 2011). Specifically, this study investigated

how two sixth-grade teachers responded to a PLC focused on incorporating problem

solving into the mathematics classroom. This study provided a glimpse at six combined

components of a professional learning community that supported teacher change.

Additionally, this study identified certain characteristics that may explain differences in

teachers' changes. Additional research should be conducted to determine the

effectiveness of the six components on a larger scale and to establish what other

characteristics contribute to differences in teacher change. The more information that

researchers can provide in these two areas, the more likely schools will be to establish

professional learning communities capable of supporting teachers in changing their

beliefs, knowledge, and instructional practices to reflect the evolving vision of school

mathematics. The final goal, of course, is to provide all of our students—with their

various capacities, backgrounds, and learning styles—the ability to learn and use

mathematics.

APPENDIX A: INTERVIEW GUIDE FOR PRE-INTERVIEW

Participant:
Date:
Grade/Subjects Currently Teaching:
Number of Years in Teaching:
Grades/Subjects Previously Taught:

1. What were your experiences as a mathematics student? How have these experiences influenced your instructional practices?

2. How do you describe your approach to teaching mathematics? How did you develop this approach?
PROBE: Coursework, staff development, resources, co-workers, etc?

3. How do you think students' best learn mathematics?
PROBE: What instructional practices/materials assist students in learning mathematical concepts?

4. How do you plan your mathematics lesson?
PROBE: What resources, information, etc. do you use?

5. What does a typical mathematics lesson look like in your classroom?
PROBE: What are the parts of the lessons; how are the students sitting/grouped; what materials, resources, technologies, are used?

6. As a mathematics teacher, what are your strengths? What are the areas you feel you need more help with or would like to learn more about?

7. How do you incorporate problem solving into your mathematics classroom?
PROBE: What activities do you do and how often do they occur? What does problem solving look like in your classroom?

8. What do you see as being the easiest part of teaching mathematics? What do you see as being an obstacle(s) in planning and implementing mathematics lessons?
PROBE: What makes teaching mathematics easy? What makes teaching mathematics difficult?

9. What mathematical concepts do you feel are the most difficult for your students to grasp? What do you try to do to assist them in understanding these concepts?

10. Is there any other information that you would like to tell me about mathematics teaching and learning?

APPENDIX B: INTERVIEW GUIDE FOR POST-INTERVIEW

Participant:
Date:

1. What have you learned about mathematics teaching and learning from this experience?
PROBE: Have you learned anything new about teaching and learning mathematics from participating in this teacher learning experience?

2. How do you plan to use what you have learned in your teaching?
PROBE: How will you use what you learned to plan mathematics lessons? What additional resources might you need?

3. What might be difficult about implementing such instruction (problem-solving activities) into the classroom?
PROBE: Time, curriculum load, etc.?

4. What did you learn about how students learn and think about mathematics? How will this influence your instructional practices?

5. What do you think about the type of professional development that you participated in?
PROBE: Was this professional development activity beneficial? How and why?

6. In your opinion, how does this professional development compare to others you have participated in?
PROBE: Strengths and weaknesses of this type of professional development? Thoughts about using the Students' Thinking Sheets?

7. Is there anything else that you would to add about this entire year-long experience?

APPENDIX C: "DECORATION DELIGHT" PROBLEM-SOLVING ACTIVITY

Decoration Delight

The Problem
The owner of a greeting card store, Winnie Winter, wants to decorate the front window with pictures of snowmen. She wants each snowman to be different, so she will use four different colors: one color for each head, scarf, middle section, and bottom section of the snowman. Winnie has asked your group to help her. In a letter, explain to Winnie how many different snowmen she can display in the window if she uses four different colors. Also explain to her how you got that number (she wants to be sure she understands your thinking).

After all that, Winnie changes her mind. She cannot decide on four colors. She is thinking of choosing from 5 or 6 colors to decorate the four different parts of the snowman. Figure out how many different snowmen she can create from 5 colors (only 4 of the five colors will be used on each snowman) and then from 6 colors. Do you see any patterns?

Add to your letter what you found when choosing from 5 and 6 colors. At the end of the letter, help Winnie make a decision about how many colors to use (4, 5, or 6) and explain why you think that choice is the best.

APPENDIX D: TEMPLATE FOR STUDENTS' THINKING SHEET

Description of Solution Strategies	Mathematics	Effectiveness
Strategy #1:		
Strategy #2:		
Strategy #3:		

What Shapes Can You Make?

Use four isosceles triangles (see below) to create as many shapes as you can. All four triangles must be used. One entire edge from each triangle must be lined up with another triangle's edge. How many different figures can be made? One example is shown.
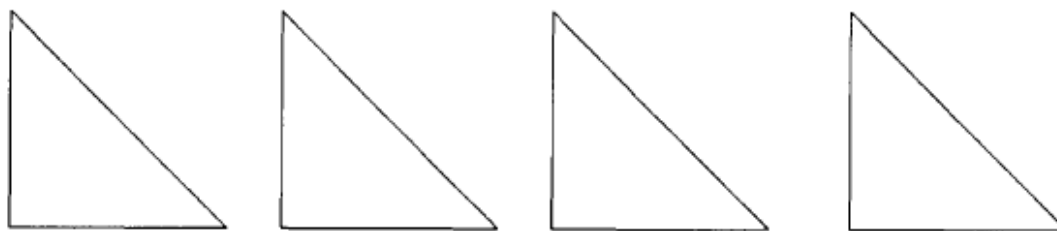

One example:
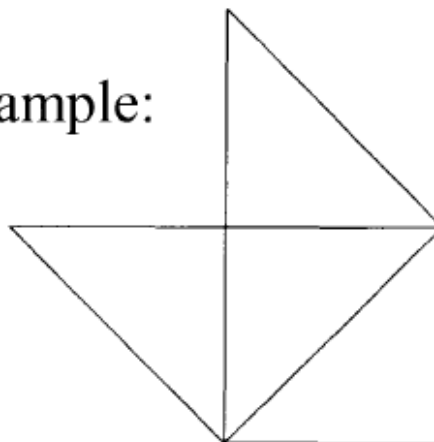
Keep track of the different shapes you are making by either drawing them on a separate piece of paper or by using the mini triangles and gluing them onto a separate piece of paper. (You only need one set of shapes per group).
Hint: Be careful to look closely at your figures. All the figures should be different, not the same (congruent) but turned to a different direction.

Counting Squares

The steps below are made of squares. How many can you count?
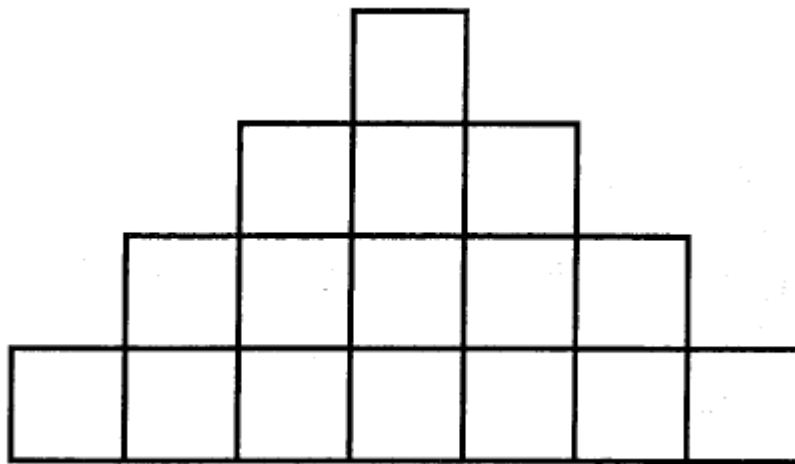
What if you add another row at the bottom? How many squares can you count now?

Continue adding rows along the bottom. Can you find a pattern that describes how the total number of squares is growing?

Extension:
Lastly, explain your thinking and counting process. Write an informative letter to someone you know explaining how you counted the squares starting with the four rows and adding one each time. What strategy for counting did you use? What type of squares did you count? How did you make sure you counted ALL the squares? What patterns did you notice?

APPENDIX G: "THE BUDGIE" PROBLEM-SOLVING ACTIVITY

The Budgie Problem

A bird collector wants to buy 100 budgies and wants to spend exactly $100. Blue budgies cost $10 each, green budgies cost $3 each, and yellow budgies $0.50 each. The collector wants to purchase at least one budgie in each color. How many blue, green, and yellow budgies can he buy?

APPENDIX H: "MARBLES" PROBLEM-SOLVING ACTIVITY

Marbles

Sheryl was excited when she arrived home with three small boxes of marbles. She labeled each box with its contents. One box had 2 blue marbles, a second box had 2 red marbles, and the third box had 1 blue marble and 1 red marble. The next morning, she found that her mischievous little sister, Angelica, had played a trick on her. Angelica had removed all of the labels and placed them back on the boxes so that **each box was labeled incorrectly**.

Sheryl wanted to put the correct labels back on **without** opening the boxes. She wondered if she could figure out the correct labeling by just seeing the color of **one marble in one box**.

Your Task:

(1)   Decide if it is possible for Sheryl to pull 1 marble from 1 box and know the correct labels for all three of the boxes.
(2)   Design a clear way of displaying your mathematical reasoning for each possibility that you considered.
(3)   Include a written explanation as to how you chose the outcome that you thought was correct and eliminated the incorrect choices.
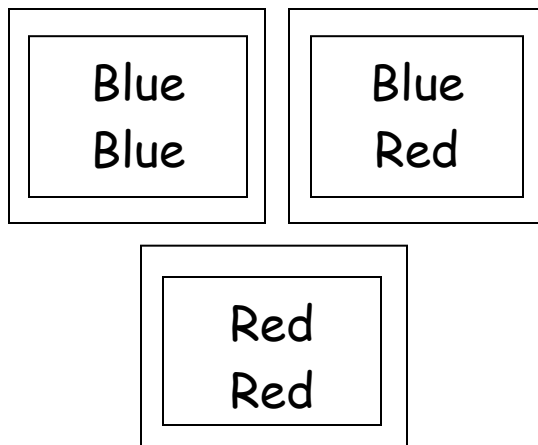
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