DEVELOPING A PROTOCOL FOR DESCRIBING PROBLEM-SOLVING INSTRUCTION

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ABSTRACT

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This study uses a qualitative approach to examine problem-solving instruction when implementing the Common Core State Standards for Mathematics (CCSS). Problem-solving instruction has previously been discussed using three approaches: teaching about, for, and through problem solving (TAPS, TFPS, TTPS). Fourteen teachers who participated in a CCSSM professional development program (PD) were studied. Specifically, their lesson plans and videos after the PD were used to describe and classify features of each approach. Results indicate that there are commonalities and differences between TAPS, TFPS, and TTPS. The elements that are consistent in all lessons observed are pre-assessment, group work, and routine problem application. The crucial difference in TAPS is the focus on learning of heuristics and/or processes of problem solving; whereas, the foci on teaching for problem solving are in helping students to understand concepts and procedures in problem solving as well as to use the knowledge gained to solve problems. The teacher's aim in teaching through problem solving is having students learn a concept or procedure through an experience engaged in problem solving; moreover, the teacher provides a focused learning environment for students to discover several ways to solve a problem and promotes discourse in the mathematics classroom.

I dedicate my research work to my lovely parents. I also dedicate this work and give special thanks to my advisor, Dr. Tracy Huziak-Clark, whose words of encouragement, tenacity, and motivation helped me to complete this portion of my education.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

CHAPTER ONE INTRODUCTION

Problem solving is important to develop students' understanding of mathematics and should have a prominent role in the mathematics curriculum (Cai & Lester, 2010; National Council of Teachers of Mathematics [NCTM], 2000; Wilson, Fernandez, & Hadaway, 1993). NCTM stated in its *Agenda for Action* that problem solving must be the focus of school mathematics (NCTM, 1980). Teachers can "enhance students' problem-solving performance as well as their representation use during problem solving" (Bostic, 2011, p.49), depending on their approach to problem solving instruction. Schroeder and Lester (1989) clarify three distinct ways to distinguish between three approaches to problem solving instruction: teaching *about*, *for*, and *through* problem solving. Each approach has distinct tasks and emphases in students' learning.

It is important to include problem solving in everyday instruction to benefit students' problem-solving performance (Bostic, 2011). However, incorporating problem-solving skills in the mathematics curriculum is not an obvious task for all mathematics teachers (Cai & Lester, 2010). Teachers, school administrators, mathematics experts, and politicians designed a clear and consistent curriculum framework called the Common Core State Standards Initiative (CCSSI). The initiative was intended to better prepare students for college readiness and careers (National Governors Association Council, Council of Chief State School Officers [NGAC, CCSSO], 2010). These standards were adopted in 45 states and four territories as of June 2014. The Common Core State Standards of Mathematics (CCSSM) describe the mathematical concepts and procedures that students are expected to learn at K-12 schooling (NGAC, CCSSO, 2010). Because of the shift in standards, many teachers want professional development activities to better adapt their instructional practices to meet the changing demands of CCSSM (Bostic & Matney, 2013; Olson, Olson & Capen, 2014). Professional development should provide an opportunity for teachers to re-examine their instructional practices in order to ensure that classroom tasks are aligned with the content framework and skills they are expected to teach (Bostic & Matney, 2014). However, "too many teachers of mathematics remain professionally isolated and with inadequate opportunities for professional development related to mathematics teaching and learning" (NCTM, 2014, p.2). NCTM (2014) addressed this reality and provided a set of strongly recommended practices that ensure professional development and adequate training for all mathematics teachers.

Connecting the CCSSM and the NCTM

The CCSSM suggested eight standards for mathematical practices (SMPs) which are: (1) make sense of problems and persevere in solving them, (2) reason abstractly and quantitatively, (3) construct viable arguments and critique the reasoning of others, (4) model with mathematics, (5) use appropriate tools strategically, (6) attend to precision, (7) look for and make use of structure, and (8) look for and express regularity in repeated reasoning. These SMPs are a guide for effective mathematics instruction. Effective implementation of these practices demands more than just focusing on each standard. Unfortunately, K-12 teachers struggle to understand and apply SMPs accurately (Bostic & Matney, 2014). Furthermore, SMPs focus on students' mathematical behavior and habits that students should acquire while learning mathematics (Bostic & Matney, 2014) more than focusing on what teachers should do in the classroom. Thus, the main goal of NCTM is to fill this gap between development and implementation of CCSSM and effective teaching practices in the classroom (NCTM, 2014). Eight Mathematics Teaching Practices (MTPs) were suggested by NCTM (2014) as a means to frame teachers' mathematics instruction (see Table 1). Research suggests that the MTPs need to be consistent components of every mathematics lesson (NCTM, 2014). These teaching practices aim to promote student learning and provide a framework for strengthening teachers' practices (NCTM, 2014).

Researcher Subjectivity

In order to better understand how a researcher might analyze and make recommendations about data, it is important that the researcher subjectivity be clear (Peskin, 1988). I taught mathematics for ten years in Saudi Arabia. The first two years I taught in a small desert middle school, grades seven through nine, without access to communication technology such as phone or internet. Each class had just three to five girls because all Saudi Arabia's schools are separated by gender. These students did not have basic knowledge nor interest in mathematics. For example, I asked them to describe a rectangle but no one could describe it or even draw it. Consequently, I focused on teaching them basic knowledge and skill acquisition in mathematics. These same girls also had difficulties in solving routine problems, so I rarely exposed them to non-routine problems. After two years, I could transfer to another middle school that was located in a rural district. Each class had 20 to 25 girls, and the girls here had stronger mathematics backgrounds. I tried to engage the girls by focusing on the importance of mathematics in real life. I spent two years in this school then I moved to an elementary school for five years in a large city with approximately 35 students in each class. These students cared about learning and had a good foundation in mathematics. In this teaching position, I was able to participate in many courses about teaching problem-solving strategies. It was easy to learn new strategies but difficult to immediately apply them during my instruction. Over time, it became easier to apply this approach. In this final placement, I was able to help students engage in more challenging tasks that required higher levels of thinking than previously. I shifted my focus from just explaining the content to teaching strategies which could engage students and increase their ability to understand problem solving. I provided more scaffolding for students' thinking in mathematics and developed their abilities in using mathematics knowledge through the use of real-life problems.

Table 1

The Eight Mathematical Teaching Practices Defined

Protocol	The goal of this practice is
Establish mathematics goals to focus learning.	to guide instructional decisions.
Implement tasks that promote reasoning and problem solving.	to engage students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.
Use and connect mathematical representations	to deepen understanding of mathematics concepts and procedures and as tools for problem solving.
Facilitate meaningful mathematical discourse.	to build shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments.
Pose purposeful questions.	to assess and advance students' reasoning and sense making about important mathematical ideas and relationships.
Build procedural fluency from conceptual understanding	that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems.
Support productive struggle in learning	to engage in productive struggle as they grapple with mathematical ideas and relationships.
Elicit and use evidence of student thinking	to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

As a part of my job, looking for professional development is important especially with the continuous transition of the mathematics standards. I considered teaching and learning problem solving as the most difficult part in mathematics especially in inclusive classrooms. Not all students have the past experiences and knowledge to apply mathematics concepts and procedures quickly or to engage in classroom activities. On the other hand, problem-solving instruction is very important to develop students' understanding in mathematics. I wondered whether or not problem-solving instruction could assist students to think creatively and what instructional strategies are necessary to do so.

Statement of Purpose

During my teaching career, I observed educators teaching problem solving in many different ways. Some of them focused on problem solving knowledge acquisition and practicing word problems while other teachers focused on problem solving concepts and procedures. However, expert teachers I observed tended to focus on the use of problem solving in real life. I did not observe any instructor employ *teaching through problem solving* (TTPS). Some instructors did not promote problem solving or even problems. I believe my experience was typical. Therefore, this research could be useful to mathematics teachers and those whose goals are to foster teachers' problem-solving instruction. Also, it is useful for the people who are involved in the development of mathematics curriculum to focus on skills required that are attained from each approach.

My goal was to find a way that assisted teachers to promote problem-solving instruction. Professional development may help teachers in their first attempt to apply new learning skills, but usually teachers need time and several attempts to master new practices. Therefore, I developed a rubric that helped teachers, teacher leaders, and curriculum coordinators to evaluate mathematics instruction. In this rubric, I provided detailed descriptions of strategies for each approach in problem-solving instruction. I presented many examples of each strategy to elucidate proper ways to apply each practice.

Research Question

This study intended to distinguish between the different types of problem-solving instruction. Its purpose was to differentiate between TAPS, TFPS, and TTPS in the standards-based era. My research question was: "What are descriptors of teaching for, about, and through problem solving in grades 4-6 mathematics teachers' instruction?"

Definition of Terms

Professional Development – training to improve teaching skills.

Common Core State Standards – high quality academic standards that outline what a student should be able to accomplish by graduation.

Mathematical Discourse – the act of representing mathematics between students and teachers or between students together.

Learning Environment – a combination of social and physical qualities that engage students in mathematics classroom.

Metacognition – thinking about one's own thinking and self-regulation during problem solving.

Routine Problems – emphasizes the use of sets of known procedures which called practices.

Non-routine Problem solving – a goal-oriented activity; that means "trying to solve the problem … [by] looking for productive paths to a solution, perhaps by brainstorming, exploring related problems, exploiting analogy or racking his or her memory for something relevant" (Schoenfeld, 2011, p. 23).

CHAPTER TWO REVIEW OF LITERATURE

Since the meaning of problem solving is important as the first step to implement problem-solving instruction as a professional (Schoenfeld, 1992), I proposed some specific definitions of this term, because knowing the meaning of problem solving can direct teachers to incorporate meaningful activities that develop students' understanding of mathematics. In addition, understanding the meaning of problem solving can lead to different implementations in problem-solving instruction (Cai & Lester, 2010; Wilson, Fernandez & Hadaway, 1993). Three different approaches emerged in problem-solving instruction, (teaching *about*, *for*, and *through* problem solving), all of which are discussed in this chapter.

Defining Problem and Problem Solving

For many, mathematical tasks can be confused with mathematics problems, and over time this has caused conflicting meanings and a variety of definitions of problem solving to be used by researchers (Chamberlin, 2010; Schoenfeld, 1992). Historically, Polya (1945) described problem solving as a practical skill, like swimming, that can be acquired by imitation and practice in which understanding mathematics is the goal rather than memorization. In the 1970s and 1980s, the definition of problem solving was expanded to focus on processes and strategies that cover cognitive activities (Lesh & Zawojewski, 2007; Schoenfeld, 1992; Sweller, 1988). According to NCTM (1980), when developing and expanding the definition and the language of mathematical problem solving, it is important to include an extensive range of strategies, processes, and modes of presentation that include the full prospect of mathematical applications. Thinking in a productive way demands that the problem solver be able to interpret a situation mathematically, and usually involves iteration of interactive cycles of expressing, examining and revising mathematical interpretations, as well as integrating, modifying, and refining mathematical concepts (Lesh & Zawojewski, 2007).

However, more recently, Schoenfeld (2011) argued that a problem is defined as depending on the relationship between the task and the individual; a task that can be a challenge for someone, may be an exercise for another one. Hence, what makes a task a problem is the amount of challenge required. When a problem is not challenging or can be solved by a familiar procedure, it will be considered an exercise (Schoenfeld, 2011). Schoenfeld's definition of problem solving consists of three components that direct students' understanding: "the existence of a solution is uncertain…, making sense of the problem situation [,] and the means necessary for making decision" (Yee & Bostic, 2014, p.2). In general, problem solving is tackling a problem that does not have a known solution. This modern definition serves as the researcher's frame.

Problem-Solving Instruction

"Solving problems is not only a goal of learning mathematics but also a major means of doing so" (NCTM, 2000, p. 52). Incorporating problem solving into instruction as a primary goal to learn mathematics has widespread acceptance (NCTM, 1980; Schroeder & Lester, 1989; Wilson, Fernandez & Hadaway, 1993) but the struggle is in the fashion in which it is implemented. A great deal of research in mathematical problem solving has been conducted to develop and propose a list of problem-solving strategies, effective activities for classrooms use, and a guideline for evaluating students' performance in problem solving (i.e., Montague & Dietz, 2009; Schoenfeld, 2010; Polya, 1945). These research studies provide useful guidelines for teachers to focus on problem solving during instruction; however, these directions are not clear enough because there is little agreement on how to achieve problem-solving goals. Moreover, there are differences among teachers and researchers on the meaning of the recommendations to make problem solving the focus of school mathematics (Schroeder & Lester, 1989). Three approaches to problem solving instruction have been distinguished to describe differences in problem-solving instruction, which are TAPS, TFPS, and TTPS (Schroeder & Lester, 1989). Each of these approaches has different instructional goals that impact students' learning in unique ways.

Teaching about problem solving. Those who employ TAPS encourage Polya's (1945) problem-solving strategies. They focus on understanding the framework of problem solving and acquisition of mathematical skills in solving problems. In this approach, students are taught a variety of methods and strategies (such as draw a figure, looking for similar problems, and looking backwards) to practice and have experience in applying different routine problems to solve non-routine problems (English, Lesh, & Fennewald, 2008). Initially, this approach was explained by Polya (1945) when he described heuristics. Heuristic implies "serving to discover [and aims to] study the methods and rules of discovery and invention" (Polya, 1945, p.102). That is, this type of teaching focuses on teaching students the problem-solving process and/or a number of heuristics rather than learning mathematics (English, Lesh, & Fennewald, 2008, p.32). In general, TAPS "always involves a great deal of explicit discussion of, and teaching about, how problems are solved" (English, Lesh, & Fennewald, 2008, p.32).

The main limitation of TAPS is that "instead of problem solving serving as a context in which mathematics is learned and applied, it may become just another topic, taught in isolation from the content and relationships of mathematics" (Schroeder & Lester, 1989, p. 34). That is, such an approach is considered as a topic of mathematics rather than regarded as a context in which students can learn and apply mathematics. Furthermore, TAPS exclusively focuses on helping students understand the problem-solving process as separate from doing mathematics (Schoenfeld, 1985).

Teaching for problem solving. The aim of teaching for problem solving (TFPS) is that students will apply learned skills, procedures, and concepts to solve problems (e.g., Boaler, 2002;

Rusbult, 2012; Schoenfeld, 2010). Teachers focus on the acquisition of mathematical knowledge and the ability to use this knowledge in real-life problems. Students are given many examples of mathematical concepts and procedures to have opportunities to apply their knowledge to solve problems (English, Lesh, & Fennewald, 2008). In short, the reason to learn mathematics is to be able to use the knowledge gained to solve problems. The mathematics that is taught can be applied in the solution of both routine and non-routine problems (Franke, Kazemi & Battey, 2007). Teachers in this approach are "very concerned about students' ability to transfer what they have learned from one problem context to others" (English, Lesh, & Fennewald, 2008, p.32).

Schoenfeld (1992) asserts that in order to promote students’ mathematical thinking and reasoning, teachers should utilize explicit instruction that focuses on metacognitive aspects. Sternberg (1986) states that metacognition is responsible for "figuring out how to do a particular task or set of tasks, and then making sure that the task or set of tasks are done correctly" (p.24). Teaching metacognitive skills in problem solving demands that teachers should work as a guide among students, and encourages purposeful discussion to make students’ behavior part of their nature or unconscious assimilation, and function as a model of good behavior (Lester, Garofalo, & Kroll, 1989).

The limitations of this approach can be when students are unaware of basic mathematical problem-solving strategies; they do not view mathematics as an area that they could make sense of (Schoenfeld, 2013). The students may not have an idea about what they should ask to develop their understanding. Schroeder & Lester (1989) stated another limitation in this approach which was it applies to routine problems better than non-routine ones. This limitation was recovered in the final approach: TTPS.

Teaching through problem solving. In this approach, problems are valued as the main purpose for learning mathematics and the primary reason to learn it (Schroeder & Lester, 1989). The teaching of a mathematical topic begins with a problem situation that embodies key aspects of the topic (i.e. project base learning) (Schroeder & Lester, 1989). A goal for learning mathematics is to transform certain non-routine problems into routine ones (Schroeder & Lester, 1989).

Teaching mathematics through problem solving entails providing a learning environment for students to explore problems by themselves and to discover ways to solve a problem. Such an approach allows students to make links of related or similar problems, to construct their mathematical knowledge and think creatively (Krulik & Rudnick, 1994; Polya, 1945). Schroeder & Lester (1989) asserted that the focus is students' understanding rather than solving problems because mathematics is seen as a way of thinking and organizing students' experiences. Further, students develop mathematical habits of mind as a result of learning mathematics through problem solving (Levasseur & Cuoco, 2003) such as guessing, analyzing, finding patterns, and justification. The "central role of interactive and cooperative learning through small-group work and whole-class discussions" (Verschaffel & De Corte, 1997, p. 582) is an important aspect of this approach of teaching.

More recently, a study conducted by Bostic (2011) to examine teaching mathematics through problem-solving contexts found that a focus on TTPS had a positive effect on students' problem solving. This study focused on two sixth grade groups in which one of them was taught through problem solving and the comparison group experienced TFPS. The main focus of the study was students' performance in problem solving as well as their use of different representations. The results from this study indicated that the students who taught using TTPS approach had a positive effect on their problem-solving performance and that students used more representations than the control group.

Teachers have a critical role in fostering the mathematical environment in the classrooms and guiding mathematical discourse among students (Franke, Kazemi, & Battey, 2007). Mistakes made by students help in the revelation of misconceptions and mistakes by the students. Hence, this method has high validity in the learning process, provided students are given sufficient time to reflect on the day's lesson (Toh, 2011).

NCTM (2014) focuses on students' needs to learn mathematics through exploring and solving mathematical problems, which is the same goal of TTPS approach. The belief that students can learn mathematics only after they are taught the basic skills and knowledge (i.e., traditional teaching) is unproductive. NCTM (2014) asserts that teaching mathematics should be focused on developing students' understanding of mathematical concepts and procedures through problem solving, discourse, and reasoning rather than focusing on practicing procedures and memorization skills. In order to develop students' understanding, teachers should engage students in tasks that encourage high level thinking and promote problem solving (NCTM, 2014). When students engage in active inquiry and exploration of mathematical problem solving tasks, these tasks are viewed as placing higher order thinking demands on students (NCTM, 2014)

The limitation of this approach may be that not all teachers have the ability to develop problems that allow students to discover mathematics concepts of each lesson. TTPS is time intensive. It requires reflective thinking about the connection between a teacher's deep connected web of mathematics ideas and his/her instructional program (Bostic, 2011). However, curriculum developers can make improvements by suggesting some purposeful mathematics problems that meet all requirements of each lesson.

In order to differentiate between traditional and non-traditional problem-solving instructions, I discuss traditional teaching next.

Traditional Mathematics Teaching

Most traditional teaching of problem solving consists of transmitting facts, skills, and concepts to students while knowledge is not created or invented by the students (Clements, 1990; Tinzmann et al., 1990). Traditional teaching emphasizes direct instruction and lectures; students learn through listening and observation (Schwerdt & Wuppermann, 2011). Moreover, focusing on memorizing facts and having correct knowledge is more important than understanding mathematics problems. In traditional teaching, teachers rely heavily on tasks such as exercises and verbal representations of exercises intended to be story problems. Students are exposed to non-routine problems if there is extra time within the lesson. They usually teach concepts and procedures first, then the students practice what they learned through solving routine story problems (English, Lesh, & Fennewald, 2008). This way of teaching actually does not engage students in problem solving because it is primarily focused on content-driven instructional perspective (English, Lesh, & Fennewald, 2008). Most story problems are considered to be exercises for students to practice procedures because they are not typically problematic enough (Cai & Lester, 2010). For example, suppose a teacher presented students with the procedure for finding the perimeter of a quadrilateral. Students practiced using the perimeter formula in a number of context-free exercises. Then, the teacher presents students with a task asking them to find the perimeter of a rectangle given the width and length of one side. Students might add these numbers and double the result to get the answer without understanding the problem situation. Routine story problems rely upon memorization tasks more than developing understanding. In a traditional teaching approach, teachers usually list problem solving as a minor topic in the curriculum (Schoenfeld, 1992). Accordingly, this situation has produced a generation of students who performed poorly on measures of thinking and problem solving due to lack of experience and exposure (Schoenfeld, 1992).

The Importance of This Study

Stein and her colleagues (2003) argued that in the next decade, important research questions in the field of problem-solving instruction will focus on “what happens inside classrooms in which problem-solving approaches are used effectively” (p. 250). In my study, I focused specifically on classroom-based implementation. My research question was: “What are descriptors of teaching for, about, and through problem solving in grades 4-6 mathematics teachers’ instruction?” As states and districts adopt new standards that focus more on reasoning and sense-making, teachers should align their instructions to meet the new learning standards. An explanation of how effectively applied these standards are strongly needed in order to improve teachers’ classroom instructional skills. Although many PD programs have been offered to support teachers’ understanding and pedagogy on MTPs (Bostic & Matney, 2014b), most “professional development today is ineffective. It neither changes teacher practice nor improves student learning” (Gulamhussein, 2013, p.3). However, the primary reason for the failure in improving teachers’ skills is the lack of supporting teachers during implementation of new learning skills in their actual classrooms (Gulamhussein, 2013). Teachers need time and several attempts to implement new learning skills (Gulamhussein, 2013). In this study, I chose participants from a PD that aimed to further teachers’ understanding of practices discussed in the MTPs and fostered teachers’ problem-solving instruction. They were asked to videotape their classroom instruction after they were exposed to teaching problem solving, through readings, experiences, and illustrations. Thus, I developed a protocol through this study to help teachers in their attempts to effectively implement problem-solving instruction. In this protocol, I provided examples of teachers' practices for each of the three types of problem-solving instruction to support teachers to be completely successful on the transition of CCSSM and help them to implement the skills necessary in each approach. I explained how teachers promote problem-solving instruction that aimed to address the CCSSM in each approach. Prominent strategies in problem-solving instruction were classified with some examples from teachers' actions in their classrooms setting. Thus, this classification of strategies could help teachers to know what strategies that they should change to move toward a different approach in teaching problem solving or to implement each necessary strategy for a specific approach.

Summary

The prominent developments on problem solving in mathematics were begun by Polya's (1945) research in promoting mathematical problem solving at the college level. The emphasis on teaching problem solving during mathematics includes three different approaches, TAPS, TFPS, and TTPS. The most important thing in problem-solving mathematics instruction is what students should know and be able to do by focusing on tasks and skills that develop their own thinking and experiences on mathematics.

CHAPTER THREE METHODS

Incorporating problem solving meaningfully into mathematics instruction is not necessarily obvious; however, previous research provided useful directions and strategies for teachers to teach problem solving in ways to develop students' understanding (e.g, Montague & Dietz, 2009; NCTM, 2014; Polya, 1945; Woodward et al., 2012). The purpose of this study was to examine TAPS, TFPS, and TTPS in the upper elementary (i.e., grades 4-6) to provide useful information about the implementation of problem-solving in elementary schools. This study aimed to identify the phenomenon of problem-solving instruction in the standards-based era. My research question was: "What are descriptors of teaching for, about, and through problem solving in grades 4-6 mathematics teachers' instruction?"

Research Design and Methodology

I chose to utilize qualitative research methods in my research to derive meaning from complex data that had been gathered with a broad focus in mind. These data were collected from teachers' lessons and videos to be used for examining the instructional tasks and its implementations. The primary characteristic of qualitative research is interpretation (Erickson, 1986). The key questions in qualitative research are: "What specifically is happening in teaching problem solving? and "What does this mean for effective teaching and learning through problem solving?" Qualitative methods provide a systematic approach to deal with large amounts of data; hence, researchers can feel confident when their reports are representative of the social conditions they are examining (Hatch, 2002).

More specifically, I used the constant comparative method of qualitative analysis (Glaser, 1965) to compare newly-collected data with previous findings elaborated in earlier studies. The constant comparative method involves four stages: "(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory" (Glaser, 1965, p. 439). The purpose of using this method is to generate an idea or theory systematically by joining coding with analysis (Glaser, 1965).

Context. This study focused on teachers from fourth-, fifth-, and sixth-grade classrooms. These teachers participated in a PD program to improve their understanding of the CCSSM and thereby their pedagogy overall. Nearly 50 K-10 teachers participated in Common Core for Reasoning and Sense-making program [$(CO)^2RES$] offered by professors from a northwestern university, which was designed to provide PD for teachers about the CCSSM. The $(CO)^2RES$ program provided opportunities for teachers to further their understanding of the Standards for Mathematical Content (SMCs), SMPs, and MTPs. The goals of $(CO)^2RES$ were to develop instructional practices that promote problem solving through reasoning and sense-making tasks as well as to model learning environments and encourage teachers to be familiar with CCSSM. Teachers who participated in the $(CO)^2RES$ attended several training sessions at the University.

During the spring sessions, participants met each other with the PD leaders for 18 hours. Teachers were asked to submit lesson plans and videotapes of their instructions. These sessions were focused on two things: exploring mathematics problems and making sense of the CCSSM. During the summer sessions, participants attended a two-week Summer Institute for a total of 64 hours. The PD leaders evaluated the teachers' lessons and gave feedback to the teachers. These sessions were focused on content learning through the SMPs. Finally, during the 18-hour fall sessions, participants were connecting theory with practice. Teachers were asked to construct two lessons and videotape their instructions. In sum, one lesson was video-taped after attending 18 hours of PD and the second lesson was video-taped after attending 80 hours of PD. During these sessions, participants focused on understanding the SMPs and MTPs frameworks.

Participants. There were 23 mathematics teachers from different school districts who participated in the 2013 and 2014 $(CO)^2$RES PD and videotaped their problem-solving lessons. Some of the teachers decided to co-plan; however, they did not co-teach the lessons. The implementation varied from teacher to teacher. Teachers who experienced PD in 2013 co-developed the same lesson plan for fourth grade and the same lesson plan for fifth grade. Furthermore, in the PD 2014 primary, teachers also co-constructed the same lesson plan for fourth grade and the same lesson plan for fifth grade, based on what they learned during the PD. In the PD 2014 secondary, the teachers who teach fourth, fifth, and sixth grade had individually-developed lesson plans. I viewed 14 of the 23 videotapes of fourth, fifth, and sixth grade classrooms. Teachers were given pseudonyms to protect their identities.

Data Sources

Data were collected using two sources: teachers' lesson plans and video tapes of the lesson plans. Teachers submitted lessons that included the following nine required details: (1) CCSSM and SMPs, (2) the lesson's objective(s), (3) the lesson's resources and materials, (4) introduction, (5) body of lesson, (6) conclusion, (7) the ways that they used to engage English Language Learners (ELLs) and students with disabilities in their lessons, (8) formative and summative assessment(s), and (9) answer keys for tasks.

Next, the teachers videotaped their lessons in a way that captured both their actions and students' actions, but the focus was clearly on the teacher and his/her instructional actions. They had approximately 80 hours of PD when they submitted their post-PD videos. The videos lasted approximately 20 – 50 minutes. I used post-PD videos to categorize the three types of non-traditional problem-solving instruction to increase the opportunity to see all three types of teaching problem solving.

Pre-Development of Observation Protocol

Using the review of literature about TAPS, TFPS, and TTPS, I developed an observation protocol to describe these approaches in problem-solving instruction. First, I read the literature and focused on the properties of each approach in problem-solving instruction. Second, the categories in this protocol were taken directly from the research on each three approaches (see Appendix A). Next, I included a section for each category in the protocol to write two to three examples of teachers' practices and to clarify how these categories could look in the actual classroom. This protocol was used to compare teachers' practices in the observed videos with the literature to ensure consistency.

Data Analysis

Data from teachers' lesson plans and videos were analyzed using the constant comparative method (Glaser, 1965) of qualitative analysis. Lesson plans were used to make sense of the lesson's tasks to confirm that the lessons were focused on problem solving and were appropriate for this study. Videos were used to see if the lesson's tasks and implementations followed the lesson plans and then were compared with the initial protocol. The initial protocol was used also to analyze and code teachers' practices of the three types of problem-solving instruction. The data collection protocol (DCP) (Appendix B) was used to write the description of teachers' practices and classify them. After classification, themes and examples were used to develop the final observation protocol. A constant comparison method was used to examine all of the data sources. Each data source will be explained individually and then a deeper explanation of how the constant comparison method was applied will be presented.

Lesson plans. Initially, lesson plans were used to provide content for the videos and to identify the instructors' road map for the lesson. The lesson plan provided descriptions of the activities that students need to learn as well as the planned strategies for implementation. Lesson plans were used to identify lessons' goals and to clarify the purposes of activities that were implemented in the classroom. Lesson plans were also used to determine if the teachers co-developed or individually developed the plans. In addition, the lessons were examined for the types of problems (routine or non-routine), level of prior knowledge considered, and the type of assessments that were planned. Data from the lesson plans were recorded on the DCP. Each lesson plan was reviewed prior to watching the video. Lesson plans were revisited as necessary for clarification throughout the coding process.

Video-tape of classroom practice. Next, each teachers' submitted video was viewed repeatedly. Videos were used as the main source in this study. Erickson (1986) illuminated the significance of the use of videos when he stated "audio or audiovisual records of frequent and rare events in the setting and in its surrounding environments provide the researcher with the opportunity to revisit events vicariously through playback at later times" (p. 144). The videos were watched and reviewed without taking notes to monitor teachers and students' actions, the implementations of lesson's tasks, and discussions. Next, each of the 14 videos was watched two to three more times, using the DCP to code teachers' practices and the time of these actions to be able to code practice to protocol for later deeper analysis. The use of the constant comparative method provided guide-lines to analyze the videos. The four stages of the constant comparative method were used during the videos' observation and resulted in developing a post-protocol, which is described below.

Post-development of observation protocol. After initial data coding of the lesson plans and video analysis, I used the constant comparison method to begin to compare the findings from this study to those that were identified in the literature and used in the pre-observation protocol.

The first step in this method is “comparing incidents applicable to each category” (Glaser, 1965, p. 439). Thus, I started by coding teachers’ practices in each video, keeping in mind the descriptions of each of the three practices, TAPS, TFPS, and TTPS from the pre-protocol that was developed using the literature review. The second stage of analysis was “integrating categories and their properties" (Glaser, 1965, p. 440). In this stage, the teachers who use the same approach were compared with each other in order to compare and contrast their practices. For example, in Ms. Boesky’s video, she guided her students during the process of solving a problem in the way that students could use what they know about decimals to add decimals using base ten blocks. I compared this action with the categories in the pre-protocol and coding it as TFPS because it fits with an original category in TFPS, which was focusing on the students’ ability to use knowledge gained to solve problems. In addition, I compared Ms Boesky’s practices with those of other teachers’ practices that were also coded as TFPS. These comparisons to the pre-protocol and within cases led to the next stage of constant comparison.

After coding three more teachers (Ms. Garcia, Ms. Erickson, and Mr. Jackson) applying the same practice, which was guiding students during the process of solving a problem, I compared these four teachers’ practices together; then I started to generate this practice as a theoretical property of TFPS. The third stage was “delimiting the theory” (Glaser, 1965, p. 441). As the teachers’ practices for each approach became clear, I started to determine the commonalities and differences between these practices. At this stage there were also several codes that could not be compared to the pre-protocol as they were not included at that time (pre-assessment). However, there was overwhelming evidence for these codes in comparison between the 14 teachers observed. They were also included in the final protocol because of this internal consistency.

The final stage was “writing the theory” (Glaser, 1965, p. 443). To develop the post-protocol, all teachers’ practices that were observed were then classified under each approach were brought together for summarizing and providing examples for each one then writing them in a post-protocol (see Appendix C).

Validity

I took the following steps to ensure the validity of the results throughout the process of analysis:

- Provided detailed description of practices discussed in the protocol for each of the three types of problem-solving instruction. According to Glesne (2006), rich or thick description is a way to increase the trustworthiness of a qualitative research.
- Provided persistent observation (Glesne, 2006). I watched each video one to two times without taking notes to monitor and make sense of teachers and students’ actions. Then I watched each one two additional times using the protocol developed to categorize teachers’ practices. Finally, I observed them again after analyzing and categorizing teachers' actions to make sure that teachers' practices were identical with the interpretation.
- My desire to understand the three problem-solving approaches and explain distinct practices in each approach led me to be very careful in collecting and analyzing the data. As Glesne (2006) suggests, clarification of researcher bias such as reflection upon her or his own subjectivity is used in qualitative research to verify the research procedures. Thus, I addressed my bias by continuously reflecting on my own subjectivity. My bias appeared in chosen videos from Post-PD to focus on teachers who learned new skills in problem-solving instruction. I also focused on teachers who teach 4-6 grade levels because my experience and interest were in teaching these grade levels. Moreover, I taught problem

solving using TAPS and TFPS approaches which could lead me to compare my goals of using a strategy with the teachers' goals of using similar strategies.

Limitations

There were some limitations in the use of videos. One of these limitations could happen if the teachers have anxiety in using technical equipment during teaching. Teachers should also have experience in video as a medium for focusing and observing interactions between them and their students. Some of these videos did not capture students' work; therefore, there was no way to know if teachers modified their practices depending on their students' work. Furthermore, some videos did not record the concluding activities in the classroom that may have helped to evaluate teachers' strategies.

Summary

The purpose of this study was to examine the mathematics problem-solving instruction and construct a protocol to classify it as TAPS, TFPS, and TTPS. Qualitative methods were conducted to interpret the results from teachers' lesson plans and videos. The results from these methods are discussed in the next chapter.

CHAPTER FOUR RESULTS

The intention of this research was to analyze teachers' implementations in TAPS, TFPS, and TTPS. Specifically this study sought to answer the following research question: "What are descriptors of teaching for, about, and through problem solving in grades 4-6 mathematics teachers' instruction?" Fourteen teachers' videos and lesson plans were analyzed to better understand their instructional practices with respect to problem solving. This chapter describes the teachers' practices of the three types of problem-solving instruction by focusing on a detailed account of their lesson planning and implementation. The findings showed several common practices as well as differences in approach based on the type of problem-solving instruction a teacher employed (i.e., about, for, or through).

Common Practices for Problem-Solving Instruction

After reviewing the lesson plans and submitted video-taped lessons, I noted many commonalities across the lessons, including recognizing students' prior knowledge, having students work in pairs or small groups, and applying different routine problems. Each of these instructional decisions that represent common practices will be illustrated more fully in the descriptions below.

Recognizing students' prior knowledge. All of the lesson plans and videos reviewed included a plan for beginning the lesson. These plans also focused on strategies for understanding what students already understand. Pre-assessment, engagement, thinking about the topic, building new information upon students' prior knowledge, or getting students ready to learn were key to understanding students' prior knowledge. One strategy used by several teachers was reviewing previous skills and content knowledge. For example, Mr. Jackson began his lesson by writing the numbers 138,456 and 1,111 on the smart board. Then he asked the students "tell me the family?" A student pointed at the number 138,456 and said "ones, tens, hundreds, thousands, ten thousands, and hundred thousands." Mr. Jackson asked another student to read this number. The student read it successfully. For the second number (1,111), Mr. Jackson asked the students to tell the family and read the number. Then he asked "who could tell me what the difference between this one and this one is?" While he pointed at the ones place and tens place. A student answered "it is the same eleven" Mr. Jackson said "you are right, they are ones but there is something different about them." Another student said "they are four ones." Mr. Jackson smiled and asked another student "what is this one; what is its value?" while he pointed at the ones place. The student answered "one, the second one is ten, and the third one is a thousand." This procedure allowed Mr. Jackson to assess students' prior knowledge about place values of whole numbers.

Another example of activating prior knowledge before problem-solving instruction came from Ms. Dixon's instruction. Ms. Dixon began the lesson by asking her students to "start with the smallest two digits, multiply by 9, plus 3, subtract 1, times 5, minus 30, divided into a half, add the number days in a week, divide by 7, and multiply by 3." Then a student said it should be 18. Ms. Dixon told her students that this lesson is similar to the adding decimal lesson that they completed in fourth grade. The warm-up activity by Ms. Dixon activated students' prior knowledge of numbers and order of operations to prepare for lesson's focus. Ms. Dixon wanted to make sure that her students were familiar with different operations to be able to use them correctly to solve current problems.

Students work in pairs or small groups. Most of the lessons had specific plans for students working with peers either in pairs or small groups. In most of the lessons, students had an opportunity to trade their ideas with another student and make sense of a problem with others. For example, Ms. Long asked a student to model the number 27 using base ten blocks. When the student finished, Ms. Long modeled the number 27 ten times to make 270 in the front of the class.

She divided her students into pairs to model the numbers 15 and 150 using base ten blocks then compare the place value of these numbers. Each group worked together while Ms. Long observed them and provided immediate feedback.

In another example, Ms. Alan wanted students to practice adding decimals to hundredths, regroup as necessary, and use base ten blocks. She divided the students into small groups to play a game using a dice and base ten blocks in order to discover the relationship between place values. Each student in a same group had an opportunity to roll the dice and model the number then add decimals and discuss the results with his or her peers.

Applying different routine problems. Through examination of the lesson plans and viewing of the videos, it was clear that most problem-solving instruction ended with exercises. When students become familiar with the procedures of solving a problem, the following problems that can be solved with the similar procedures were considered as routine problems or exercises. In the observed videos, the students were given exercises to complete after they finished solving a challenging problem or after their teacher provided an example in how to solve a problem. For example, Ms. Fisher's lesson focused on students' ability to create then compare (using <, =, >) multi-digit numbers using their knowledge of place value. She started her lesson by solving a problem as an example. She wrote on the board "Make two numbers smaller than five thousand with a two in the tens place then compare the numbers using <, >, or =." She read the problem then said "the first thing that we need to do is fill in the numbers that were given to you. So we need to put a two in the ten place in both numbers. So where is my ten place?" She kept asking the students a lot of questions to figure out what should they do to solve this problem. When the problem was solved, Ms. Fisher gave students ten problems similar to the example provided but with different numbers. Thus, these ten problems were considered practices because the students were taught from the example provided who to solve these type of problems.

Each element, pre-assessment, group work, and routine problem application were consistent in all lessons observed. This suggests that beyond the type of problem solving instruction, there are still commonalities that exist in mathematics lessons.

Differences in Teaching Practices during Problem-Solving Instruction

Each approach in problem-solving instruction has distinct traits that distinguish it from others. The following description comprises two examples of two different teachers for a same practice in TAPS, TFPS, and TTPS (see Appendix C). Further elaboration of the Appendix C is shared next.

Teaching about problem solving. A key trait that makes TAPS distinct is the focus on teaching heuristics and/or problem-solving processes. TAPS is best characterized as teaching the procedures of problem solving such as teaching Polya's model (Schroeder & Lester, 1989). Furthermore, there is a direct focus on the framework of problem solving in a clear and simple way led by the teacher with the students following along.

For instance, Ms. Crawford, a fourth-grade teacher, taught students various strategies to solve word problems. Her focus on understanding problem-solving procedure during the lesson provides an example of how the teaching procedures in solving problem tends to purposefully separate mathematics from problem solving. Ms. Crawford focused on the importance of using the four steps procedures and encouraged her students to use heuristics to solve problems. She asked them to underline important information such as numbers and circle the labels in word problems. Next, she asked “what do I need now?” The students put a circle around the phrase “multiplicative comparison.” Ms. Crawford asked students to put the total amount at the end. Then she asked, "We should multiply the underline number with what to get the total?" The students put (? X 3 = 21). She asked the students to look backwards to solve the problem by using division. A student said (21 ÷ 3 = 7). Then she asked the students to make sure that they understood the solution by rereading the word problem. Ms. Crawford concentrated on teaching problem-solving procedure by focusing on four interdependent phases to solve problems. The first phase focused on understanding the problem. For example, Ms. Crawford asked the students to underline important information. She directed students' attention to think about existing information to understand the situation in the problem. The second phase was devising a plan. Hence, Ms. Crawford asked students to circle the label to focus on the necessary operation to solve the problem. The students could see that multiplication was the required operation. Then they wrote the word problem as an equation with help from Ms. Crawford. The third phase was carrying out the plan; she suggested that they work backward by using division to solve the equation. That is, she led the students to use a heuristic strategy, which was working backward in devising and carrying out their problem-solving plan. For the fourth phase (looking back), Ms. Crawford asked students to reread the word problem to understand how they could get a solution in order to use this method for solving future problems. The most focus in Ms. Crawford's lesson was on the method of solving problems and not the mathematics.

In addition, Ms. Patrick, another fourth grade teacher, focused on translating a word problem into symbols first, then completing the procedures. Her goal was that students be able to evaluate other students' solutions using four-point rubric. Ms. Patrick gave the students five minutes to solve a problem then evaluate their solutions. The word problem was: Anna has 5 times as many stickers as Melissa. They have 30 stickers all together. How many stickers does Melissa has? Ms. Patrick clarified what she expected to see in the students' solutions, which included:

drawing a model, writing an equation, solving the equation, as well as interpreting the result. The students worked individually to solve the word problem while the teacher observed them. In the front of the class, Ms. Patrick showed the students how was drawing a picture to model the word problem is important and helpful to solve problems. Ms. Patrick focused on learning to solve problem and had nothing to do with learning mathematics.

Teaching for problem solving. TFPS is similar to explicit instruction in which a series of supports or scaffolds during problem solving are applied but explicit instruction not always involves problems. In TFPS, the teacher aims to help students learn mathematics so they might solve problems.

For example, Ms. Boesky, a fifth grade teacher, taught a Number and Operations in Base Ten lesson. Her goal was for students to be able to add decimals to hundredths, regroup as necessary, and use base ten blocks. Ms. Boesky asked the students to roll the dice and then use base ten blocks to model the result. She said, “roll the dice, then grab that many tenths”. Then she asked the other student in the same group to roll the dice and grab that many hundredths. The students were asked to model then write their result as a decimal. The students wrote 0.51 and it should be 0.15; Ms. Boesky asked them to correct the mistake by asking the students “Which number should go to the tenths spot?” Then the students erased the mistake and wrote the right decimal. She asked the students to play four extra times and put all model numbers in a pocket. When Ms. Boesky made sure that the students learned and understand the meaning of decimals and knew how to model decimals using base ten blocks, she gave them a problem, which was adding decimals. She asked them to add the numbers in the pocket. While the students were working in adding decimals, Ms. Boesky told the students that they could regroup as necessary. After the students finished counting and trading, they wrote the result on their small white boards.

Ms. Boesky wrote the numbers that students had on the board and added these numbers with the students. Then she checked with the students that they had the same number on their boards. Ms. Boesky aimed to help her students use what they knew to add decimals by providing scaffolding for students' thinking during the process of solving problems.

Another fifth grade teacher, Ms. Dixon, also used a dice game to help her students to learn the procedure of adding decimals. Her goal was "students could add decimals to hundredths, regroup as necessary, and use base ten blocks." She showed an example of how to play using dice and base ten blocks. In the front of the class, she rolled a dice twice and wrote the result. Then she pretended an invisible partner to roll the dice twice. Ms. Dixon counted the both numbers and added them together then wrote the final result. When she finished, she asked her students to do the same activity five times as small groups. The students followed the same procedures that were modeled by the teacher to solve the given tasks, which were modeling and adding decimals, but with different numbers.

Teaching through problem solving. The key trait of TTPS is the use of a focal problem to guide students' thinking in exploring mathematics concepts and procedures (Schroeder & Lester, 1989). Furthermore, an inquiry-oriented environment is an essential element in TTPS. Mathematical concepts and procedures should be learned in the context of solving problems (Bostic, 2011; Schroeder & Lester, 1989). In this approach, teachers connected students' prior knowledge with the problem at hand but this connection may not sufficient. Thus, students could search for a method to solve a problem and use what they know to guide them during problem solving.

For example, Ms. Hopkins taught Operations and Algebraic Thinking for fourth grade. Her goal of the lesson was that students would be able to find factor pairs of a given number. In the front of the class, she presented the goal of the lesson by saying "I can find factors of a specific group." Then she engaged her students by asking them to pretend that they were going on a field trip and they should divide themselves into three equal groups without help from the teacher. The teacher said, "Someone tell me what would you do to figure out the groups." One student answered "24 ÷ 3= 8," while another student answered that he added the numbers to find 3 x ? = 24. Another student said he counted them up. Ms. Hopkins asked the students to prove that the group numbers were equal. One student made the suggestion to put each group against each other. The teacher followed what the student suggested and lined up the three groups. Then she asked if the students could draw a picture or use the counters to represent these groups. Following that, Ms. Hopkins read this problem: "Eighty fourth grade students at Andrews Elementary School are going on a field trip. Their teachers need to put between 3 and 25 students in each group to visit the shark tank. How many different ways can the teachers group their students so that each group has the same number of students?" Notice that this problem is open-ended, challenging and has the possibility for many correct answers. She asked the students to solve this problem individually for five minutes, then they could look for a partner to see what their partner found. The students were allowed to use any method to solve the problem, such as using counter pieces, pictures, or crayons. She monitored the students while they worked. After around 30 minutes, Ms. Hopkins said, "I need someone who be able to show us what you did to find your solutions." A student said "I have 20 students in four groups" and held up a picture for the answer. Ms. Hopkins asked, "Is there a way to put the data to know how many kids and how many groups to display it a little more clearly?" A student said that we could draw a picture while another student said that we could use a T chart. Ms. Hopkins asked, "How could we use a T chart?" The same student said, "We can put how many groups in a side and how many students in the other side." Then Ms. Hopkins asked the students if somebody else had another way to solve the problem. A student said "10 students in 8 groups" and he explained how he got this answer while another student said that she got eight students in 10 groups. The students noticed that they could use commutative facts to get other pairs such as: five students in 16 groups and 16 students in five groups. Thus, they could come up with the whole pair factors of the number 80 that met the problem's requirements.

Ms. Hopkins began with a task that activated and illustrated students' prior knowledge and connected the topic with the students' experience. The aim in this lesson was to learn how to find factor pairs of a given number through an experience engaged in problem solving. She led the students to work together to figure out how to divide themselves into three groups. The students could begin to analyze how to find some of the factors of 24. This activity could help them in the goal "find factor pairs of a given number" for the new lesson. Ms. Hopkins stimulated mathematical discourse and reasoning when she asked the students to think of multiple ways to find the answer; she asked them "What would you do to figure out the groups?" When the students were given a challenging problem, they were allowed to access to manipulatives or any method they believed would help them, such as drawing a picture or using counters that help to interpret the solution. Ms. Hopkins did not give the students direct instructions about how to solve the problem; consequently, the students used more trial and error while solving the problem. Because the problem was challenging and open-ended, students were able to use multiple problem solving techniques and approaches to find a variety of responses that fit the criteria. The students were encouraged to work collaboratively, to talk about their thinking, and to draw conclusions.

Another example in TTPS was with Ms. Alan. Ms. Alan's goals were that students could add decimals to hundredths, regroup as necessary, and use base ten blocks. She asked the students to work as pairs to add decimals using dice and base ten blocks. Then she said, "Can you imagine a situation that you might have a whole lot of these (she showed units that represent hundredths in her hand) and you want to trade them for something else?" Ms. Alan divided her students into small groups to discover the relationship between ones place and tenths place. The students worked together for approximately twenty minutes. Then, during a whole-class discussion, Ms. Alan asked the students to tell her about something they learned or something they noticed after doing this activity. A student said that he "noticed some times he ended with one whole." Ms. Alan said, "Tell my about the one whole thing" and "Is it more likely to end up with a one whole or less likely?" the students answered "more likely." She kept asking the students questions such as "why did you trade every ten tenths with a whole while you adding decimals?" The students responded "because ten tenths are the same as the one whole." She followed with the question "What is the math difference between ones place and tenths place?" They said "ten times bigger." Ms. Alan provided opportunities to her students to construct their mathematical knowledge. The students could discover by themselves how to get a whole number from adding decimals and that place value is ten times bigger than the place on its right. The rich discourse in the class led the students to engage in mathematical thinking and reasoning.

Summary

There were a number of commonalities between TAPS, TFPS, and TTPS. These approaches in problem-solving instruction were initiated with applying students' prior knowledge of a procedure or concept. Moreover, the students worked with peers as pairs or small groups. It was common for instruction to end with exercises. Nevertheless, there were some differences between problem-solving instructions. Each approach had distinct traits that enabled to distinguish it clearly from other types.

Three different approaches in problem-solving instruction (TAPS, TFPS, and TTPS) were distinguished by providing examples of teachers' implementations in the classroom setting. Each of these approaches has different emphases in students' learning. As a result of the analysis, I was able to develop a protocol to categorize instruction as TAPS, TFPS, and TTPS, as long as problem-solving instruction was a part of it.

CHAPTER FIVE DISCUSSION AND CONCLUSION

Purpose of the Study

This study was conducted to describe teachers' practices of three approaches in problem-solving instruction. These approaches were TAPS, TFPS, and TTPS; each of them had different emphases on teachers' practices. Classifying problem-solving instruction aims to fulfill successful implementations and facilitate how to implement each type effectively.

Application of Protocol to the Data

This study's research question was "What are descriptors of teaching for, about, and through problem solving in grades 4-6 mathematics teachers' instruction?" The themes illuminated from this study were the commonalities in teachers' implementations of problem-solving instruction, which were pre-assessment, group work, and routine problem application (see Appendix C). The first common practice between these approaches was recognizing students' prior knowledge. Teachers were attentive about students' ability to evoke their previous mathematical skills, procedures, and concepts to use them during problem solving. In addition, teachers endeavored to connect new learning to students' prior knowledge and experiences to make instructions more meaningful. The second commonality was that most teachers divided their students to work into pairs or small groups. However, some of them gave students several minutes initially to think individually and make sense of the given problem before working in groups. The third common practice was applying exercises (an exercise or routine problem means that students have familiarity with a problem's procedure). Although TAPS, TFPS, and TTPS mostly ended with exercises, there was a minor difference in the emphasis on the time and amount of exercises. The majority of the time in lessons identified as TAPS and TFPS was spent applying exercises while lessons identified as TTPS included applied exercises if there was extra time in the lesson.

In addition, there were important differences between TAPS, TFPS, and TTPS that helped to frame key ideas of each approach. In TAPS, the general trait was a focus on teaching heuristics and/or procedures in problem solving. Teachers focused on teaching the framework of problem solving, which was separate from learning mathematics.

Teachers who applied TFPS concentrated on guiding students' thinking during the process of solving problems with immediate feedback as a way of preventing or correcting errors during solving a problem. Teachers focused on learning procedures with a goal of applying the knowledge to solve problems as well as exercises by providing an example of how to solve a problem.

Moreover, TTPS lessons began with a challenging problem. Teachers could give students an open-ended problem that had several right answers and/or several ways to get the right answer. Students were asked to show their work, explain how they got their answers, and clarify why they chose the technique they did to get the answer. In this type of teaching, teachers asked insightful questions that developed logical thinking and encouraged students to improve and build onto their own procedures in solving problems. Furthermore, teachers provided a focused learning environment for students to explore problems individually then to discover multiple ways to solve problems with peers. They asked students a lot of questions that guided their thinking to discover a new concept or procedure while students worked in small groups to trade their ideas. As a result, the students constructed their mathematical knowledge from their experiences; the students interacted, discussed, and shared their ideas with peers during the process of solving a problem.

Adaptation of the Observation Protocol

There were some changes in the protocol categories from the pre- to post-protocol. Some categories did not remain in the post-protocol, because the findings did not support them. Changes in the protocol from pre- to post- will be discussed below relative to each of three approaches of TAPS, TFPS, and TTPS

Development of TAPS. More specifically, the categories that existed in pre-protocol and were not seen in the post-protocol in TAPS were emphasizing direct lecture and applying different routine problems to solve non-routine ones. I did not observe TAPS teachers emphasize direct lectures, and the students were not exposed to non-routine problems (see Table 2). What was observed was that teachers focused on teaching problem-solving procedure and encouraged the use of heuristics as separate from learning mathematics. Then students were exposed to routine problems to solve them as pairs or small groups.

Table 2

Comparison of TAPS Observation Protocols

Type of teaching	**Pre-protocol**	**Post-protocol**
TAPS	X	Recognizing students' prior knowledge
	X	Teaching problem-solving procedure
	X	Group work
	Applying different routine problem to solve non-routine problems	X (Students did not solve non-routine problems)
	Emphasize direct instruction and lectures	X

Development of TFPS. In the TFPS pre-protocol, there was a focus on students' beliefs and dispositions about problem solving but I did not include this category because there was no focus on it in my teachers' sample. However, the missing data might not have been seen in the observed videos, because I watched one video per teacher; it could have been observed in another lesson or another grade level such as second or third grade. Moreover, I did not observe that the teachers focused on students' ability to transfer what they had learned from one problem context to another. What I observed was that students were exposed to routine problems after they solved a non-routine problem with guidance from their teacher or after their teacher provided an example of how to solve a problem (see table 3).

Table 3

Comparison of TFPS Observation Protocols

Type of teaching	**Pre-protocol**	**Post-protocol**
TFPS	Focusing on students' beliefs and dispositions about problem solving	X
	Focusing on students' ability to transfer what they have learned from one problem context to another	X (Students solve exercises)

Development of TTPS. Most teachers who TTPS gave their students one or two routine problems after they finished solving a non-routine problem. According to her lesson plan, one of the teachers planned to give her students a routine problem put her video ended immediately after the students finished from solving a non-routine problem. Students were exposed to routine problems if there was time in the lesson (see table 4).

Table 4

Comparison of TTPS Observation Protocols

Type of teaching	**Pre-protocol**	**Post-protocol**
TTPS	X	Applying different routine problems

New categories. There were some teachers' practices that were observed in the videos and included in the post-protocol but had not existed in the pre-protocol. In TAPS, these practices emphasized pre-assessment, group work, and problem-solving procedures. These teachers stressed recognizing students' prior knowledge, because all teachers began their lessons by determining what students knew about a topic and gauging their readiness to start new instruction. Furthermore, learning problem solving rather than learning mathematics was the main theme in this approach because most observed teachers focused on teaching problem-solving procedure and some strategies in problem solving. Then the students were exposed to routine problems to solve them as pairs or small groups. In TTPS, I included the category "applying different routine problems" in the post-protocol, because most observed teachers who used TTPS gave their students some routine problems if there was time in the lesson.

In the post-protocol, I included one to two examples of teachers' practices in their actual classrooms. The selection of these examples in the pre-protocol was dependent on the maximum variation sampling method. This method "aims at capturing and describing the central themes or principal outcomes that cut across a great deal of participant variation" (Patton, 1987, p. 53). I chose examples that clearly demonstrate the properties of each approach in teaching problem solving. The maximum variation sampling method appears strengthened when some common practices occur from great variation of teachers' implementations (Patton, 1987). Thus, in the post-protocol, I intended to write examples of the common practices of teachers who use different approaches in teaching problem solving.

Implications

This study confirmed previous findings in which teachers who teach about problem solving focus on teaching heuristics and strategies of problem solving. Schroeder and Lester (1989) stated that teachers who use TAPS emphasize Polya's model of problem solving and a number of heuristics such as working backward or looking for a pattern, which moves to focus students' cognitive energy on the heuristic use rather than the mathematics being learned. Verschaffel et al. (1999) also confirmed that teaching a number of heuristics can increase students' problem-solving abilities. The main goal in this approach is to learn problem-solving procedures that tend to separate problem solving from learning mathematics.

Moreover, TFPS is akin to explicit instruction in the sense that teachers' goals are to support students' learning of a procedure or concept so that they can apply their knowledge to solve problems. Teachers provide clear guidelines for identifying concepts or procedures and give students opportunities to practice routine problems (Archer & Hughes, 2011). Moreover, teachers provide an example of a new concept or procedure in solving a problem; students are introduced to a new concept first then problem solving is applied as an activity to engage students in the lesson. Schroeder and Lester (1989) stated that in TFPS, "students are given many instances of the mathematical concepts and structures they are studying and many opportunities to apply that mathematics in solving problems" (p. 320). Consequently, students can solve routine problems better than non-routine ones.

The findings confirm prior research in TTPS that teachers begin with the use of students' prior knowledge to engage them in a challenging problem. Bostic (2011) asserted that TTPS "should build upon students' prior knowledge and experiences and facilitate creating a network of mathematical topics, skills, and strategies" (p. 49). In all of the TTPS videos, students were allowed to discover multiple ways to solve a problem with their peers in pairs or small groups with free access to the use of tangible materials. Then as a whole-class discussion, their teacher asked insightful questions to arrange and share their results. Schroeder and Lester (1989) stated that the teaching of a mathematical topic in TTPS starts with a problem using an inquiry-oriented process while mathematics concepts and procedures are learned in the context of solving problems. In addition, all of the videos observed also showed the positive end of classroom routines that included sharing results and reviewing of meaningful findings. Bostic (2011) noted that in TTPS, teachers encourage students to share their results during the whole-class discussion. In addition, teachers in TTPS conclude the day's instruction and reflect on the concepts and skills learned by the use of whole-class discussions (Bostic, 2011).

There is a connection between emphasizing problem solving and emphasizing understanding. Indeed, teachers are encouraged to use TTPS more than the others (e.g., NCTM, 2008; Schroeder & Lester, 1989). The theme that makes TTPS favorable is its aim of learning mathematical concepts and procedures through an experience engaged in problem solving. TTPS "benefits students' problem-solving ability and the number of representations used to solve word problems" (Bostic, 2011, p. 160).

This study supports mathematics classroom teachers as well as professional development (PD) leaders. First, the observation protocol may be used by teachers during their attempts in mastering new learned skills in teaching problem-solving instruction. Second, this research offers examples of three approaches in problem-solving instruction that can help to fully understand the phenomena of practices in each approach and might stimulate teachers to enact lessons with different content. In addition, the examples may provide a context for pre- and inservice teachers to learn how to teach about, for, and through problem solving. PD leaders also can use this protocol as a basis to determine which practices need to change in order to move toward a different approach.

Recommendations

Although TTPS is time intensive and requires reflective thinking, I recommend using TTPS because it develops students' understanding of mathematical concepts and procedures through problem solving, discourse, and reasoning rather than focusing on practicing procedures and memorization skills. I would use the observation protocol back home and encourage mathematics teachers to use it in order to determine which type of teaching they use and which practices they need to change to move toward TTPS approach. I may conduct discussions with mathematics teachers in my school level and district about what each category in the protocol looks like. I have a protocol that I feel captures the three approaches in problem-solving instruction and is very useful for all mathematics teachers who look to improve their implementation in the classroom setting. In addition, I would recommend that PD leaders use this protocol to determine which practices that need to be focused on more than others during the PD. Indeed, it saves time and effort of PD leaders because it directs their attention to focus on specific categories needed to implement each approach. I will translate my thesis from English into Arabic language in order to expand the number of teachers and PD leaders who would read this study and use the protocol but they do not speak English.

Limitations of the Study and Suggestions for Future Research

There were some limitations in this study that effect the evaluation of results. Some classrooms were modified to consist of two to four students while others held more than 20. Moreover, some videos were ended before the lessons were wrapped up, while others contained parts from three days' lessons. In addition, some lesson plans were shared by three to four teachers; however, their implementations were different. Lastly, TFPS focuses on students' metacognition. It is difficult to know if teachers develop students' metacognition during their implementations. Therefore, there is a need for future research that explores the degree to which teachers' practices promote students' metacognition in each day's lesson.

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APPENDIX A. The Pre-Observation Protocol

Traditional Teaching practices	Teachers Actions
Transmitting facts	
Transmitting skills	
Transmitting concepts	
Emphasize direct instruction and lectures	
Focusing on memorizing facts and/or having the correct answer	
Relies heavily on exercises (routine story problems)	

Teaching about problem Solving	Teachers Actions
Focus on acquisition of mathematical skills	
Focus on acquisition of strategies	
Focus on understanding steps and procedures (explicit discussion how problems are solved)	
Emphasize direct instruction and lectures	
Applying different routine problems to solve non-routine problems	

Teaching for problem Solving	Teachers Actions
Applying learned skills to solve problems	
Applying procedures to solve problems	
Applying concepts to solve problems	

Focusing on the ability to use knowledge with real-life problems	
Focusing on students' beliefs and dispositions about problem solving	
Recognizing what students know	
Students are given many instances of the mathematical concepts and structures	
Focusing on the students' ability to transfer what they have learned from one problem context to another	

Teaching through problem Solving	**Teachers Actions**
The instruction begin with a problem	
Applying learned skills to solve problems	
Applying procedures to solve problems	
Applying concepts to solve problems	
Provides a focused learning environment for students to explore problems individually and to discover multiple ways to solve problems	
Students construct their mathematical knowledge	
Focusing on mathematical discourse and reasoning	

APPENDIX B. Data Collection Protocol

Name of Teacher:_________

Grade level: _______

Co-taught lesson:______________

Key elements of teacher's practices: ______

Teacher's gender: ______

In the space below, provide brief descriptions of what was observed during instruction and when.

Time	Description of Event	Type of teaching

APPENDIX C. Final Observation Protocol

Type of Teaching	Teachers' Practices	Teachers' Examples
Common practices	Applying students' prior knowledge	- Reviewing the multiplication facts and/or decimal system -Writing everything about a concept graphing - Giving students a warm up activity to make sure that the students recognize different operations.
	Students work in pairs or small groups	- Students work in pair groups to model whole numbers using base ten blocks. - Dividing students into small groups to play using a dice and base ten blocks in order to discover the relationship between place values
	Applying different routine problems	-Giving students worksheet to practice a new concepts or procedure such as comparison - Asking students to add decimals using base ten blocks several times
TAPS	Focus on learning heuristics and/or processes of problem solving	- Teaching Polya's four phases as separate from learning mathematics

		- Teaching and/or encouraging the use of strategies such as drawing a picture or looking backward to solve word problems
TFPS	Teachers guide students during the process of solving a problem	- Providing directions during adding decimals using base ten blocs
	Providing an example in how to solve problems	- Showing an example of how to play using dice and base ten blocks to add decimals
	Immediate feedback when making errors	- asking students to correct their mistake during working in their groups to model decimals.
TTPS	The instruction begin with a problem	- Giving students an open-ended problem and has a possibility for many correct answers.
	Provides a focused learning environment for students to explore problems individually then to discover multiple ways to solve problems with pairs	- Allowing students to use any way to solve a problem such as using counter pieces, pictures, or crayons while they working in pair groups.
	Students construct their mathematical knowledge	- Students could discover by themselves how to get a whole number from adding decimals and that place value is bigger ten times than the place on its right

	Focusing on mathematical discourse and reasoning	-Asking students a lot of question that guide their thinking to discover a new concept or procedure while students work in small group to trade their ideas.

APPENDIX D. Human Subject Review Board Approval Letter

BGSU®
BOWLING GREEN STATE UNIVERSITY
Office of Research Compliance

DATE:	April 22, 2015
TO:	Jonathan Bostic, Ph.D.
FROM:	Bowling Green State University Human Subjects Review Board
PROJECT TITLE:	[313774-11] Examining the effects of problem-solving professional development on K-10 teachers' and students' outcomes
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	January 26, 2015
EXPIRATION DATE:	December 7, 2015
REVIEW TYPE:	Administrative Review
REVIEW CATEGORY:	Expedited review category # 7

Thank you for your submission of Amendment/Modification materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The following modification was approved:

- Add Awsaf Alwarsh to the list of people who have access to the data.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on December 7, 2015. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hsrb@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.

- 1 -

BGSU.

BOWLING GREEN STATE UNIVERSITY

Office of Research Compliance

DATE:	December 9, 2014
TO:	Jonathan Bostic, Ph.D.
FROM:	Bowling Green State University Human Subjects Review Board
PROJECT TITLE:	[313774-10] Examining the effects of problem-solving professional development on K-10 teachers' and students' outcomes
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	APPROVED
APPROVAL DATE:	December 8, 2014
EXPIRATION DATE:	December 7, 2015
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # 7

Thank you for your submission of Continuing Review/Progress Report materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

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This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.

BGSU®

BOWLING GREEN STATE UNIVERSITY

Office of Research Compliance

DATE:	January 26, 2015
TO:	Jonathan Bostic, Ph.D.
FROM:	Bowling Green State University Human Subjects Review Board
PROJECT TITLE:	[313774-11] Examining the effects of problem-solving professional development on K-10 teachers' and students' outcomes
SUBMISSION TYPE:	Amendment/Modification
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REVIEW CATEGORY:	Expedited review category #7

Thank you for your submission of Amendment/Modification materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The following modification was approved:

-Add Awsaf Alwarsh to the project.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

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Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hsrb@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.