DEVELOPING PRIMARY (K-2) TEACHERS' UNDERSTANDING OF HIGH COGNITIVE DEMAND MATHEMATICAL TASKS

by

Dori L. Hargrove
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
Doctor of Philosophy
Education

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Date: _________________________________ Spring Semester 2015
George Mason University
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DEDICATION

I dedicate this dissertation to my husband, Ron, who has been a constant source of support and encouragement during the challenges of graduate school and life. His love, support and constant patience have taught me so much about unconditional love. Without lovingly providing a shoulder to cry on and then providing the encouragement and voice of reason to move me forward, I would not have achieved this goal.

I also dedicate this dissertation to the teachers who volunteered to participate in the study. Thank you for sharing with me and trusting me. I learned more than I am able to write on the pages of this document. The shared experience will always be remembered and treasured.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my advisor, Dr. Margret Hjalmarson, who supported me throughout my course work and research for this dissertation with kindness, patience and knowledge.

To my committee members, Dr. Penelope Earley and Dr. Joseph Maxwell, for their encouraging words, thoughtful criticism, time and attention throughout this process.

To my dear friend, Diane Prentice, who provided countless hours of editing, to not only this dissertation, but also many other papers I wrote during graduate school. And to Dr. Clifton Farrell who provided thoughtful edits to this dissertation.

Finally, I thank my family for their support and encouragement throughout this process. Especially to my daughter, Rebekah, who sacrificed time with me so I could finish my studies and dissertation.

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LIST OF ABBREVIATIONS

No Child Left Behind .... NCLB
National Council of Teachers of Mathematics .... NCTM
Quantitative Understanding Amplifying Student Achievement and Reasoning .. QUASAR
English Speakers of Other Languages .... ESOL
Special Education .... SPED
Instructional Quality Assessment .... IQA

ABSTRACT

DEVELOPING PRIMARY (K-2) TEACHERS' UNDERSTANDING OF HIGH COGNITIVE DEMAND MATHEMATICAL TASKS

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The purpose of this investigation was to explore the ways in which primary (K-2) teachers selected and implemented high cognitive demand tasks in their classrooms and how professional development influenced their understanding of how heeding to the type of tasks and implementation resulted in improved teaching. Extending the research of Boston and Smith (2009) and Stein, Smith, Henningsen, and Silver (2009), which was conducted in middle and secondary schools, this investigation was conducted in an elementary setting with seven primary (K-2) teachers who participated in three professional development sessions over one semester. The mixed method study utilized a quantitative pre- post design to determine any changes in how the teachers identified and implemented high cognitive demand tasks. Qualitative methods were used to describe the process of the changes in the teachers understanding. Data collected from teachers included a task sort interview, collection of student work and tasks used in the classroom,

classroom observations as teachers implemented tasks, video of the professional development sessions and participant interviews. Analysis of the data indicated that the teachers improved in their selection and implementation of high cognitive demand tasks. Implications for this study include the need for continued research in the selection and implementation of high cognitive demand tasks in primary (K-2) settings in the areas of differentiation and instruments to measure quality of instruction in primary classrooms. Education policy implications included the creation of tasks for primary classrooms and directives in how using high cognitive demand tasks fits into an already packed curriculum.

CHAPTER ONE

How much mathematics students know, how deep their understanding of mathematics and their ability to apply mathematics to solve complex problems, is a cause for considerable concern among educators in the state in which this study was conducted (Virginia Department of Education, 2014). The spotlight has been on improving schools to provide a rigorous education that prepares students for college or the work force. Standardized tests mandated by the federal government through No Child Left Behind (NCLB) do not fully measure the type of skills associated with preparing students for college and the work force. These skills include "nonroutine analytic skills such as abstract reasoning, problem solving, communication, and collaboration" (Partnership for 21st Century Skills, 2006, p. 4). The National Council of Teachers of Mathematics (NCTM) stresses, through the Principles and Standards (2000), the importance for students to solve problems and engage in mathematical thinking, reasoning, and communication. Prior to the 1989 NCTM standards, teachers were primarily encouraged to present isolated facts and algorithms for students to memorize and master (Putnam, Lampert & Peterson, 1990). Thus, NCTM called for a change in mathematics teaching. Teachers should be facilitators of student learning by providing an environment where students can engage in rich mathematical tasks, be independent thinkers, develop connections between mathematical ideas and communicate their mathematical understanding (NCTM, 2000).

At the district level where this study takes place, there is concern among district leaders as to the quality and duration of mathematical reasoning, communicating and problem solving in the classroom. To address these concerns, district leaders presented an instructional improvement focus for the 2013-14 school year. The focus was to provide professional development to prepare teachers to build relationships with students, develop students' critical and creative thinking skills through the use of high level tasks, offer access to supportive tools, and opportunities for productive talk (J.B. Kennedy, personal communication, May 9, 2014). Although the teachers in the school where I work and where I collected my data for this study know the instructional improvement focus, the teachers do not have the support necessary to learn how to implement high cognitive demand tasks, thus they continue to teach mathematics as a system of facts, procedures, and concepts (Schoenfeld, 1992). Research about selecting and implementing high cognitive demand tasks focuses on middle and secondary classrooms and, to the best of my knowledge, there are no such studies in the primary (K-2) classrooms. This study addresses that gap by focusing on how primary teachers' selection and implementation of high cognitive demand tasks in the classroom change during professional development. Further, I wish to provide a deeper understanding of the process of the change, if any, that takes place.

Mathematics Performance Tasks

The use of mathematics performance tasks can provide a window into how a student is applying mathematics to various situations, how they are reasoning mathematically and how they are applying conceptual knowledge through problem solving and critical thinking. Using cognitively demanding mathematical tasks in the classroom provides an experience whereby students can make connections between mathematical ideas and use multiple mathematical representations to construct knowledge and communicate mathematical understanding. Mathematics performance tasks provide students with an opportunity to show their mathematical thinking, conceptual and procedural understanding, problem solving ability, and mathematical reasoning skills, which are all highly valued in the reform of mathematics education (Van de Walle, 2004). Research suggests that mathematics performance tasks are successful at improving students' understanding of important mathematical concepts (Thompson & Senk, 2001) and at improving students' abilities to use the mathematics process skills outlined by NCTM (Schoenfeld, 2002).

High cognitive demand tasks are open-ended tasks that require students to construct solutions to problems in ways that demonstrate conceptual knowledge and process skills. Stein, Grover, and Henningsen (1996) define mathematical tasks as a set of problems or a single complex problem that focuses students' attention on a particular mathematical idea. According to Breyfogle and Williams (2008) a worthwhile mathematics tasks is one that "allows for connections, incorporates multiple approaches and solutions, requires high-level thinking and facilitates reasoning and communication"

(p. 277). Boston and Smith (2009) contend that a high-cognitive demand task is one that requires some degree of cognitive effort, meaning that students need to engage with conceptual ideas that underlie the procedure in order to complete the task. The task is non-algorithmic, requires complex thinking, and requires students to explore and understand mathematical concepts, processes and relationships. Further, in order to solve the task, the students need to be able to make connections from what they know and apply it to the task. Figure 1 shows an example of a low cognitive demand and high cognitive demand mathematical task.

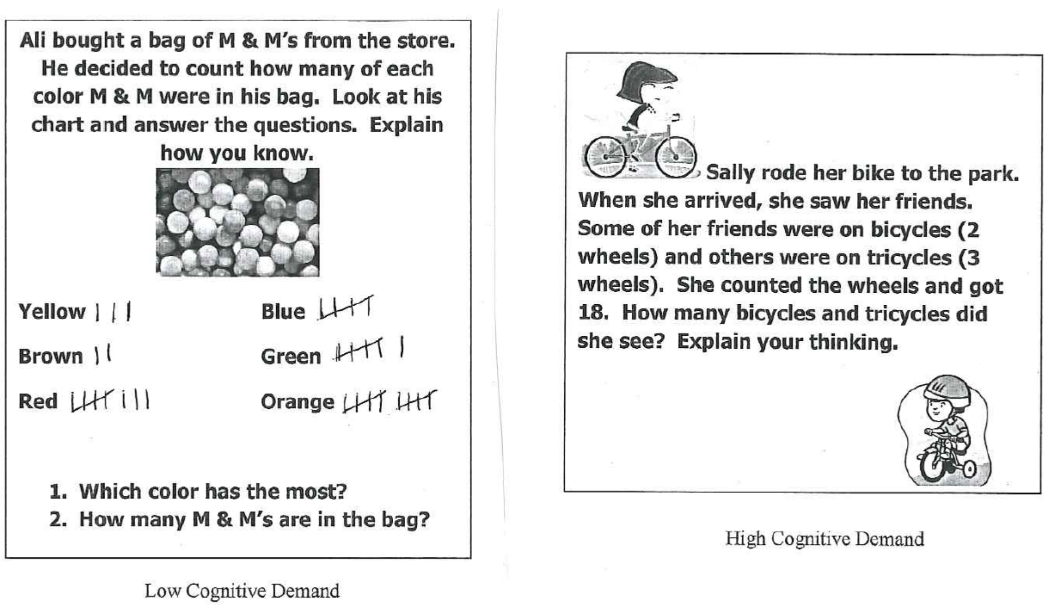


Figure 1. Example of Low and High Cognitive Demand Tasks

In the examples above, solving the low cognitive demand task merely requires counting the tally marks. Likewise, a child can determine the answer by looking for the color with the most tally marks. In contrast, the high cognitive demand task requires higher-level analysis and thinking. Children have to think about all the combinations of eighteen wheels that are multiples of two and three. For example, if the child tries the combination of one bicycle, which is two wheels, there are sixteen wheels left. Sixteen is not a multiple of three so that is not a combination. However, if the child tries three bicycles, which is six wheels, there are twelve wheels left. Twelve is a multiple of three resulting in four tricycles. Therefore, the combination of three bicycles and four tricycles is a possible answer. Another possible combination is six bicycles and two tricycles.

The purpose of this investigation was to explore the ways in which primary teachers selected and implemented high cognitive demand tasks in their classrooms and how professional development influenced their understanding of how heeding to the type of task and implementation results in improved teaching practice. My hypothesis was that providing teachers with the opportunity to engage in analyzing mathematical tasks and implementing these tasks in their classroom will empower teachers to begin selecting high cognitive demand tasks and implementing them in ways that maintain the cognitive demand thus increasing the opportunity for improved teaching. My research used and extended the body of research focused on using high cognitive demand mathematics tasks as a means to enhance mathematics teaching in ways that are consistent with current calls for 21st century learning. The research questions were:

1. Did these primary teachers' understanding of what constitutes a high cognitive demand task change after participating in professional development focused on selecting and implementing high cognitive demand tasks, and if so, how and why?

2. Did these primary teachers maintain academic rigor of classroom assignments when using mathematical tasks, and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?
3. Did these primary teachers implement high cognitive demand tasks and maintain a high level of demand that supports student engagement throughout the instructional episode and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?
4. Did the professional development influence how primary teachers select and implement performance tasks in their classrooms, and if so, how and why?

The recent calls for reform education and incorporating 21st century skills in the curriculum is changing the expected role of the teacher from dispenser of knowledge to an engineer of learning where students grapple with mathematical problems and construct their own understandings (Stein, Engle, Smith, & Hughes, 2008). Our children will inherit a world where they need to know "how to frame problems for themselves, how to formulate plans to address them, how to assess multiple outcomes, how to consider relationships, how to deal with ambiguity, and how to shift purposes in light of new information" (Eisner, 1999, p. 658). Schoenfeld (1992) argued that student learning is a process of acquiring a mathematical disposition as well as acquiring mathematical knowledge. Some characteristics of mathematical disposition are making sense of mathematical ideas, deciding if mathematical results are reasonable, and thinking and reasoning in flexible and multiple ways. If children are to develop these dispositions, then classrooms must become environments where they have opportunities to engage in rich mathematical tasks (Schoenfeld, 1994). Achieving these goals depends on teachers providing their students with engaging, high cognitive demand tasks during mathematics instruction. Therefore, teachers must know how to identify high cognitive demand tasks in order to ensure their students have opportunities to think, reason and problem solve. Additionally, teachers must know how to maintain the cognitive demand of the task when implementing the task in the classroom. When the task is implemented in the class, it becomes intertwined in complexities associated with the unpredictability of the task, and the ways in which the teacher and student reacts to those complexities (Stein, Smith, Henningsen, & Silver, 2009). Teachers can learn how to deal with the unpredictability of a high cognitive demand task by participating in well-designed, collaborative professional development.

Stigler and Hiebert (1997) argued that the best way to improve instruction in the classroom is through professional development that "is based on the direct study of teaching, with the goal of steady improvement in the mathematics learning of students" (p. 20). Other researchers agreed with Stigler and Hiebert and called for professional development that included teacher collaboration (Little, 1990; Loucks-Horsley, Hewson, Love, & Stiles, 1998). The type of change that is needed in mathematics education requires a transformation in current teaching practices that results in changes in teachers' long-held, underlying beliefs about what effective teaching and learning of mathematics looks like (Thompson & Zeuli, 1999). Therefore, professional development where teachers can reflect on their current teaching practices and learn about new ideas and experiences can result in moving teachers towards new practices that improves how they teach mathematics and improve student learning.

History of Prior Research

Research into mathematical tasks began in the 1970s and continued into the 1980s. Most of the mathematical tasks research in the 1970s concerned categorizing tasks by variables in order to research problem solving; it had little to do with informing teachers or curriculum developers' ideas. However, other researchers looked at the characteristics of the tasks and concluded that these characteristics determined the degree of success of problem solving in the classroom. Charles and Lester (1982) considered task classification as important when teachers are making choices of problems to assign their students. Task classification was not the focus of Charles and Lester's research, but they used task classification as a method for teaching problem solving.

Doyle (1983) turned to the research conducted by cognitive psychologists when considering tasks. Cognitive psychology researchers were considering the intellectual demand of tasks used in schools. Doyle suggested that tasks "are defined by the answers students are required to produce and the routes that can be used to obtain these answers" (p. 161). Additionally, he argued that if the only tasks used in a classroom require a specific answer and route, then that is all the student will learn. Thus, Doyle identified four types of tasks, (memory tasks, procedural or routine tasks, comprehension/understanding tasks, and opinion tasks), which he organized into two levels of demand. Lower level tasks include memory tasks and procedural or routine tasks, which involve memorization or using algorithms to solve problems. Comprehension/understanding tasks include higher-level thinking that engages students in application of knowledge and skills, comprehension and testing conjectures (Doyle, 1988).

Drawing from the work of Doyle (1983, 1988), Silver and Stein (1996) began the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) project. This research sought to explore the relationship between mathematical tasks and student learning. The QUASAR project was a national reform project aimed at assisting schools in economically disadvantaged communities to develop middle school mathematics programs that emphasized thinking, reasoning, and problem solving (Silver & Stein, 1996). In this study, they analyzed teacher learning and instructional change through observations and documentation of teachers' efforts to implement reform-oriented instruction. The goal of this project was to reform mathematics instruction in ways that provided students with opportunities to think, reason, and solve problems. The QUASAR project included professional development, which consisted of coursework, workshops, collaboration with colleagues, and individual reflective activities (Brown, Smith, & Stein, 1996). The professional development activities supported teachers' knowledge and beliefs and instructional practice (Brown, Smith, & Stein, 1996) as they attempted to implement a mathematics curriculum in a way that allowed students to think, reason, communicate and solve problems. Through professional development, the teachers interacted with the curriculum as learners and refined their implementation of the curriculum in their classrooms by watching videos of themselves teaching and analyzing student work.

Conceptual Framework

The framework that guided much of my dissertation research stems from work done in the QUASAR project. QUASAR project researchers developed a framework (Stein, Smith, Henningsen, & Silver, 2009) that focuses on the cognitive demand of mathematical tasks. They described this framework as the phases a task passes through during classroom instruction. First, the task appears in the curriculum the teacher is using, or, perhaps the teacher completes a Google search for a task, or the teacher creates the task. Second, the teacher sets-up the task, and third the student works on the task. According to Stein et al. (2009) "All of these, but especially the third phase (i.e., implementation), are viewed as important influences on what students actually learn…" (p. xviii). QUASAR project researchers used this framework to analyze mathematics lessons. Research suggests that mathematics tasks with high cognitive demand are the hardest to implement and student learning was greatest when the teacher implemented these high cognitive demand tasks well (Stein & Lane, 1996; Stein et al. 2009).

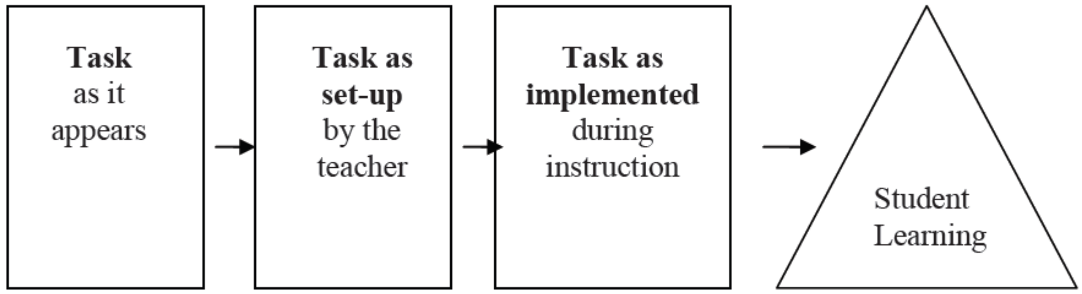


Figure 2. The Mathematical Task Framework (Stein, et. al., 2009, pg. xviii).

The first phase is the task as it appears in front of the teacher. This phase focuses on the task before it is used in the classroom. At this point, the teacher must be clear about his/her instructional goal for the lesson they are going to teach. The goal of the lesson determines the type of task the teacher should use. For example, if the goal is to assess the addition and/or subtraction fact fluency, then the task must match that goal. However, if the goal is to understand how numbers are decomposed and recomposed, then the task must be rich enough to elicit that thinking from the students. In this phase, teachers must know how to determine the mathematical thinking the task will bring out. This is why it is important for teachers to practice sorting tasks based on the cognitive demand of the task.

The second phase addresses how the teacher launches the task in the classroom. This phase includes the way a teacher communicates the expectations to the student. This might be a short or long conversation depending on the goals for the lesson, the background knowledge of the class and the teacher's expectation for carrying out the task, such as individual or small group work. The third phase, the implementation phase, starts as soon as the students begin working on the task. According to Stein et al., (2009), the students' cognitive engagement determines what is learned, but "the ways and extent to which the teacher supports students' thinking and reasoning is a crucial ingredient in the ultimate fate of high-level tasks" (p. 15). Ultimately, the implementation phase influences the level and kind of student learning.

Chapter Summary

In order to realize the goal for preparing students for the global knowledge based economy, for college or the work force, students must have opportunities to engage in complex problem solving that requires mathematical thinking, reasoning and communication. Many schools are not heeding the calls from NCTM to teach mathematics in a way that promotes critical thinking and problem solving. Using high cognitive demand mathematical tasks in the classroom and maintaining the cognitive demand when implementing the tasks provides an opportunity for improved teaching resulting in improved student learning. This type of learning provides an environment where students are independent thinkers and where they can reason, justify, make connections, and communicate mathematically.

Yet, research has suggested that teachers do not know the type of mathematics tasks that will elicit deep mathematical thinking. Worse, when implementing a high cognitive demand task in the classroom, they may lower the cognitive demand of the task through decisions they make during instruction. This investigation explored the ways in which teachers selected and implemented high cognitive demand tasks in the classroom and how professional development influenced their understanding of how heeding to the type of task and implementation results in improved teaching. In chapter two, the literature review delves into the research surrounding high cognitive demand mathematical tasks, professional development, and adult learners to form a foundation for this investigation.

Definition of Terms

High cognitive demand. Something that requires some degree of cognitive effort, meaning that students need to engage with conceptual ideas that underlie the procedure in order to complete the task (Boston & Smith, 2009).

Mathematical tasks. A set of problems or single complex problem that focuses students' attention on a particular mathematical idea (Stein, Grover, & Henningsen, 1996).

Pedagogical content knowledge. "The blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8).

CHAPTER TWO

This chapter describes the research related to high cognitive demand mathematical tasks, professional development and teacher knowledge and change. I begin with a comprehensive overview of the research on identifying and using high cognitive demand tasks in the classroom. I discuss the literature surrounding professional development and its impact on teacher change through the use of video and case studies and how what we know about adult learners influences the type of professional development we should provide teachers. Finally, I discuss what research tells us about teacher change and how teachers acquire knowledge.

High Cognitive Mathematical Tasks

Recognition of high-cognitive demand tasks requires a teacher to consider how the task provides opportunities for a student to investigate mathematics content in an open way, and to assess how well the task connects with the students' background knowledge, as well as how the task is designed to push the student to think more deeply about the mathematics involved in the task. In their book, *Implementing Standards-Based Mathematics Instruction*, Stein, Smith, Henningsen, and Silver (2009) describe how teachers classify mathematics tasks as high-level thinking tasks. First, the teachers have to consider several factors in order to determine if the task is a cognitively demanding task. Some of the factors are the grade level in which the task will be administered, prior knowledge and experience of the students, and norms and expectations for their work. Second, the teachers have to overlook the surface features of the task and carefully consider the kind of thinking the task requires. Examples of the surface features include tasks that require students to show or explain their thinking, incorporating manipulatives to solve the problem, having multiple solutions or multiple steps, or being set in a real world scenario. The authors found that teachers classified tasks as high level thinking simply because they included one or more of the above features. However, as the teachers discussed the task and looked more deeply at the kind of thinking the task was designed to bring out, they realized that the mere presence of the surface features mentioned above was not an indicator of the cognitive demand of the task. Clearly, teachers must know how to look at a task and accurately judge its cognitive demand before using it in their classroom in order to provide an opportunity for their students to engage in the type of learning associated with 21st century skills.

Current research suggests that when teachers use mathematical tasks in their classrooms, they diminish the cognitive demand of the task for various reasons (Boston & Smith, 2009; Smith, Bill, & Hughes, 2008; Stein, Engle, Smith, & Hughes, 2008). In a study conducted by Stylianides and Stylianides (2008), a teacher who was highly competent changed a mathematical task that she acquired through a reform mathematics textbook. In an interview with the researchers, she admitted that she did not know that she lessened the cognitive demand of the task when she made modifications. In fact, when she chose the task she did not consider the cognitive demand. The task was part of the lesson she was teaching and was included in the textbook, and she felt she could make it more fun and fit the time constraints of the mathematics period by making changes. Therefore, this teacher read this task and only considered how she should change it instead of considering the type of mathematical thinking and reasoning the task, as it was written, would provide her students. It is unclear whether the teacher could look at this mathematical task, as it was presented in the text, and identify the cognitive demand. Teachers struggle with identifying the cognitive demand in a mathematics task, and they struggle to understand the depth of mathematical thinking the task could elicit.

Other research suggests that teachers do not evaluate tasks based on cognitive demand; rather, they typically evaluate tasks with respect to the mathematical content and/or surface features such as "explain your thinking" or "use manipulatives to solve." In a study conducted by Arbaugh and Brown (2005), seven high school geometry teachers participated in a study in which the researchers sought to discover how learning to identify the level of demand in mathematical tasks would influence their thinking about those tasks and how they would choose to use them in their classrooms. These teachers and the first researcher met ten times, approximately once every two weeks, for what the authors referred to as a study group. The participants spent two of the study groups learning about cognitive demand in mathematical tasks and did a sorting activity, and subsequent meetings were spent engaging in activities that supported teachers as they continued to consider the cognitive demand of tasks. The participants completed two additional sorting activities, different from the one they did in the study group, when they were being interviewed by the researcher. During the first interview, prior to the study group, the participants sorted the cards creating different categories and these categories varied between the participants. However, it was relatively easy to collapse the categories that the participants created into two main categories. The first category was math content (percentages, common fractions, algebra, etc.). The second category was surface features such as real-world problem, story problem, or problem involving manipulatives. The majority of the teachers placed their cards in the surface features category. It is possible that the teachers placed more in the surface features categories because that is consistent with reform-oriented pedagogy (Swafford, Jones, & Thornton, 1997). During the second interview, after the study group meetings ended, they repeated the sort again. More of the teachers considered the thinking that the student had to engage in to complete the task. In fact, five of seven teachers had begun to use the levels of cognitive demand to categorize the tasks. The significance of this study suggested that teachers did not think of cognitive demand when initially considering tasks. This type of analysis is not common to their way of selecting tasks to use in their classroom. After learning about the different thinking levels embedded in a mathematical task, they began to look for and consider the thinking that the task would bring out as the student completed the task. However, it is noteworthy to mention that this type of learning takes time and cannot be done in the typical "one-shot" professional development sessions that are common in education settings today.

Additional research supports Arbaugh and Brown's (2005) findings. Stein, Baxter and Leinhardt (1990) also found that teachers, prior to any professional development, tend to focus on two main categories when considering tasks. Those two categories are mathematical content and surface features. Swafford, Jones, and Thornton

(1997) found that when teachers were modifying or creating tasks they could make changes that were consistent with reform-oriented pedagogy (i.e. show your thinking, solve this problem using manipulatives), but most neither increased cognitive demand nor created a task that was of high cognitive demand. Hiebert et al. (1997) found that teachers consistently used mathematical tasks that match a list of skills or content that needed to be covered and did not consider the cognitive demand of the task. Overall, it is apparent that teachers did not consider the cognitive demand in tasks when selecting, creating or modifying tasks. Yet, in a world where 21st century skills and rigor are the expectation, teachers need to know how to recognize a high cognitive demand mathematical task.

Classroom observations from the QUASAR project researchers revealed that even if the teacher selected a high-cognitive demand task and launched the task as it was written, it did not guarantee that the level of cognitive demand remained high as the students worked on the task. According to Stein, et al. (2009) only 40% of the tasks that started out as high-cognitive demand tasks remained that way once the students worked to solve the task. The way and extent to which the teacher supported the students through the task determined if he/she maintained or lowered the cognitive demand of the task. For example, Stein et al. (2009) observed that when students worked on a high cognitive task and they did not know how to solve it, they persisted in pressuring the teacher to provide steps or procedures and the teacher eventually told the students how to solve the problem. Although the teachers' have good intensions, when they deconstructed the problem, gave hints or scaffolded the task, they reduced or eliminated the opportunity for the students to think and reason, resulting in the loss of meaningful opportunities to develop mathematical understanding.

Another way teachers influenced the maintenance of high cognitive demand was if they did not provide the support necessary to maintain the demand of the task. In these cases, the teachers did not ask thought-provoking questions that moved the students thinking forward. Finally, another observation was that the cognitive level of the tasks declined when students transitioned into nonmathematical activity. The researchers observed activities such as, playing with the manipulatives, talking in groups about topics other than mathematics or concentrating on producing a poster to share out their thinking that was very artistic, but included little mathematical understanding. In these cases, the teachers did not set and/or reiterate the expectation of the use of maniuplatives, conversations in groups or, in other cases, the teachers settled for other outcomes such as students working together.

Other research suggests that teachers have difficulty maintaining the cognitive demand of a task when they implement tasks in the classroom. A study conducted by Boston and Smith (2009) concluded that teachers who, prior to participating in professional development, implemented a high cognitive demand task in the classroom reduced the cognitive demand of the task. This study investigated how secondary mathematics teachers selected and implemented high cognitive demand tasks. The lesson observations occurred in classrooms of the intervention (professional development) group and a control group. The data revealed that there were no significant differences found between the intervention and control group prior to the professional development for the intervention group. Thus, teachers who implement high cognitive demand tasks in the classroom will lower the cognitive demand of the task during the instructional episode.

Over two decades of research (Hiebert & Wearne, 1993; Stein & Lane, 1996; Stigler & Hiebert, 2004) indicate that the greatest student learning occurs in classrooms where implementation of high cognitive demand tasks commence in a fashion that consistently maintains the cognitive demand of the task during instruction. Hiebert and Wearne (1993) concluded that teaching and learning are related through the instructional task and the discourse environment in the classroom. They go on to say that these instructional factors influence the level of cognition that students will engage. Thus, what teachers do directly affects what students will learn. The data in this study revealed that two of the six classes they observed had higher performance due to the instructional task and the kind of discourse the teacher promoted. This resulted in greater student learning, because the students in those classrooms engaged in higher cognitive activities such as explaining their thinking, making connections and conjectures and questioning the thinking of each other. Further, Tarr and colleagues (2008) as well as Stein and Lane (1996) have both determined that learning environments in which teachers encourage multiple solutions, making conjectures and mathematical connections and explaining reasoning result in higher student performance.

Professional Development

Recent research on professional development focuses on what principles are present in effective professional development. Professional development refers to the development of a person in their professional role. When designing effective professional development, one must consider what learning experiences will occur and how they will take place. According to Loucks-Horsley, Stiles, Mundry, Love, and Hewson, (2010), changing the beliefs and practices of teachers requires multiple opportunities to learn, reflect, and apply new behaviors. Teachers need opportunities to alter their practice by observing and discussing a demonstration lesson. Teachers need opportunities to use their new knowledge in their classrooms and they need the opportunity to reflect on their practice by examining student work that resulted from their implementation of the new knowledge. Loucks-Horsley et al. (2010) contend that the combination of all these opportunities into one professional development yields greater benefits.

Additionally, Borko (2004) explored the links between professional development design, teacher learning during the professional development and changes in classroom practice through a review of the current literature. Through her analysis, she found four themes. The first theme was teacher content knowledge. This is an important theme because knowledge of the subject they teach is imperative to student outcome. Professional development experiences that engage teachers as learners of content promote development of content knowledge. The second theme was teacher understanding of how students learn. Professional development that included clinical interviews with students or video of students solving mathematical problems contributed to a teacher's understanding of how students learn. Third was the theme that a professional community fosters teacher learning. Professional development that allows teachers to collaborate within established norms and an environment of trust promotes teacher learning and, subsequently, changes in classroom practice. The QUASAR project is one example of this theme. The researchers of the QUASAR project analyzed the professional development data and concluded that professional communities were central in fostering teacher change and student learning. However, research in this area suggests that the development of these communities is difficult. Teachers welcome conversation around ideas and materials related to teaching, but conversations about a critical examination of teaching are harder to achieve. Professional development leaders must build an environment of trust and establish norms that promote critical dialogue. Finally, the fourth theme that emerged from the literature is the use of classroom artifacts. These artifacts could be video of the teacher teaching a lesson, copies of the tasks used in the classroom, or copies of student work to analyze in the professional development session. The research surrounding this theme revealed that these artifacts are powerful tools to enact teacher change because these artifacts enabled teachers to critique one another's instructional practice and discuss ideas for improvement. Sowder (2007) would title this theme as teacher pedagogical knowledge because it produces the type of knowledge associated with knowing how to teach a mathematical concept to a group of students. Professional development leaders who model the pedagogy of good mathematics instruction help teachers build the pedagogical content knowledge needed to teach mathematics well.

Loucks-Horsley et al. (2010) believe that effective professional development must be transformative, meaning that the professional development must literally transform the teachers' long held beliefs, knowledge and practice. Transformative professional development helps teachers to discard those ideas and begin to see the value of reform. They go on to write that beliefs develop over time through "…active engagement with ideas, understandings, and real-life experiences" (p. 76). How a teacher learned mathematics as students produced strong models of how to teach mathematics to their students. These beliefs are transformed through new understandings and experimenting with new behaviors. Transformative professional development design includes the themes identified by Borko (2004) discussed in the above paragraph. Additionally, the use of a framework to guide the design of the professional development and situating professional development in the everyday work of the teachers results in the transformation of teachers (Boston & Smith, 2009).

Researchers have studied the effects of professional development for many years. Specifically, research has focused on the design of the professional development and the effects of that design on the desired outcome. Trainings provided through workshops or conferences tend to be unidirectional where the teacher attends the professional development and listens to a more knowledgeable other. Traditional professional development formats have assumed a hierarchy where the teacher is the less knowing and the facilitator is the more knowing person (Domitrovich, Gest, Gill, Bierman, Welsh, & Jones, 2009). This type of professional development is void of teacher interaction and focuses on learning as an individual activity (Sheridan, Edwards, Marvin, & Knoche, 2009; Wood & Bennet, 2000) rather than viewing professional learning as a socially constructed activity (Fleet & Patterson, 2001; Wood & Bennet, 2000).

In contrast, learning communities is a type of professional development design where teachers interact and reflect, and facilitators' value teacher contribution (Fleet & Patterson, 2001). Learning communities are also known as discourse communities, communities of practices or professional learning communities. Putnam and Borko (2000) state that "when diverse groups of teachers with different types of knowledge come together in discourse communities, community members can draw upon and incorporate each other's expertise to create rich conversations and new insights to teaching and learning" (p. 8). This kind of interaction can occur in learning communities because it relies on constructivist theories of learning where teacher and facilitator engage in the learning experience equally (Sheridan, et al. 2009).

Fleet and Patterson (2001) state that one of the goals of professional development should be to empower learners and one way to accomplish that is to focus on the contributions of the teachers and value the knowledge that the teachers bring to the professional development. The constructivist perspective fundamental to learning communities recognizes "the unique contribution of the personal professional knowledge of individuals and the importance of the orientation of individuals both to their work and to new ideas" (p. 9). Learning communities provide a format for social construction of knowledge (Wood & Bennett, 2000). Socialization and interaction with others are important in the development of professional knowledge (Wenger, 1998) and teachers appreciate when their expertise and experience is valued. Learning communities as a model for professional development is most effective when teachers have opportunities to reflect because it enables teachers to think about their practice. When teachers communicate with others, an opportunity for questioning beliefs and practices take place. Learning communities allow teachers to engage in reflection in a supportive environment with knowledgeable others who share similar interests and who can provide different perspectives on beliefs and practices (Wood & Bennett, 2000).

Speck and Knipe (2001) emphasized that professional development program design should meet the needs of each teacher and link the learning with the immediate and real problems they face in the classroom. In successful professional development, individual teachers would be involved in the process, have choices in the planning of their program, and would be accountable for their own learning. Additionally, there were other factors to consider when designing professional development activities for teachers, based on how adults learn. Speck and Knipe (2001) list the following as a guide based on adult learning theories:

- Adults will commit to learning when they believe that the objectives are realistic and important for their personal and professional needs.
- Adults want to direct their own learning and should therefore have some control over the what, who, how, why, when, and where of their learning, as long as it meets the criteria of increasing teacher capacity to affect student achievement.
- Adults will resist activities that they see as an attack on their competence.
- Adults need direct, concrete experiences that can be used to apply what they learned to their work.

- Adult learners do not automatically transfer learning into daily practice. Sustained learning, through coaching and other types of follow-up activities, is imperative.
- Adults need to receive feedback on the results of their efforts.
- Participation in small group activities during the learning process is necessary to advance from simply understanding the new material to the desired levels of application, analysis, synthesis, and evaluation.
- Adult learners come to the professional development with a wide range of experiences, knowledge, interest and competencies.
- Adults enjoy novelty and variety in the learning experiences, and learning opportunities need to reflect this attribute (pp. 109-110).

Considering the adult in the teacher is paramount when planning professional development and following this guide will help ensure a successful experience.

Speck and Knipe (2001) define a constructivist model of professional development as one in which teachers engage in their own learning, guide their own instruction, and then evaluate their learning. Thus, teachers are involved in processing, analyzing, and examining new concepts for their own meaning and understanding. Additionally, teachers will learn skills such as self-reflection and using inquiry for assessment and improvement. Lai (1995) notes that an adult's motivation to learn comes from their current interests or needs to gain knowledge. Comparatively, a child's motivation to learn comes from the need to please parents or teachers. He goes on to say those adults learn best through participation and dialogue and not through modes of teacher-centered, lecture type approaches that ignore the adult as an adult learner. Lai confirms Speck and Knipe's view that teachers need opportunities to construct their own knowledge, to grapple with ideas they think are relevant to their instruction, and to build on their background knowledge, beliefs and instructional practice.

Use of video in professional development. Recent research suggests that classroom videos are an important reflective tool for teachers in professional development. Video captures classroom episodes that the teacher may not notice when teaching a lesson (Borko, Jacobs, Eiteljorg, & Pittman, 2008). This is what van Es refers to as noticing. van Es and Sherin (2008) define noticing as consisting of three parts: identifying what is important in a classroom interaction, interpreting the meaning of those interactions, and deciding what to do next. Sherin (2004) provides a rationale for using video because it is beneficial for three reasons: (a) it provides a permanent record of what occurred in the classroom; (b) it can be collected and edited; and (c) it can be viewed multiple times for multiple purposes.

However, Brophy (2004) cautions that embedding video in an appropriate instructional context is needed in order for it to be an effective tool for teacher learning. Teachers who view video without a clear focus tend to hone in on superficial features of the classroom instruction instead of reflecting on the type of instruction and the effect that instruction had on student learning. LeFevre (2004) agrees with Brophy, however, she also argued that watching video that contains problematic situations could result in teachers learning to take a more tentative stance in their observation, use evidence to support their opinions, understand multiple perspectives, and acknowledge personal beliefs. Sherin (2004) believes that a teacher who views video with the purpose of reflection and analysis gain a new kind of knowledge: how to interpret and reflect on their own classroom practice. Clarke and Hollingsworth (2000) found that using video clips from classroom settings that are too familiar to the teachers might be less effective in changing teachers thinking. In contrast, Brophy (2007) concluded, "Ideal videos show teachers with whom viewers can identify implementing a curriculum similar to the one they use… in a classroom similar to the classroom in which they teach" (p. 289). Perhaps the negative findings from Clark and Hollingsworth are more likely due to the use of the videos rather than anything about the familiarity of the setting (Coles, 2013).

Zhang, Lundeberg, Koehler, and Eberhardt (2011) conducted a qualitative study to investigate the advantages and disadvantages of using commercially available videos, colleague videos or self-videos in a professional development program. The researchers concluded that the participants found all three types of video beneficial, but they felt that the self-videos were most beneficial scoring the highest on a scale of one to five. Commercially available video was the least popular. Participants reported that the commercially available videos allowed them to see other teachers implement problem based learning, but the different grade levels and content made it difficult for them to relate to. However, the participants felt that they learned from models of exemplary teaching. This study revealed that there were benefits to viewing self-videos. It could be watched individually and offered an opportunity for the participants to observe themselves from a different perspective, analyze discourse, and notice more about how students were engaging in the activities.

Nemirovsky, Dimattia, Ribeiro, and Lara-Melody (2005) conducted an empirical study of teacher talk of a videotaped classroom episode. From this study, they distinguished two types of discourse. The first is “grounded narrative” where the teachers provide descriptions of classroom events. The second is “evaluative discourse” where teachers comment on the instructional videos in light of their view of what good teaching is, and then strive to assess the present circumstances. They concluded, from this study that evaluative discourse is the most prominent conversation used when watching videotaped instructional episodes. This is similar to what van Es and Sherin (2008) report on from their study of the “video club.” From their study, they report that teachers will evaluate or call into question the pedagogical decisions of the teacher and offer advice on how the teacher could have done things differently.

Seidel et al. (2005) conducted an experimental study where they compared the experiences of teachers who viewed video of themselves and those who viewed video of other classrooms. They found that teachers who watched video of their own classrooms reported that the potential for supporting their learning and promoting change in their instructional practice was greater than those who watched video of other classrooms. Results from this study support the notion that using video of teachers’ own classroom supports their learning and reflective practice, and has the potential to enact change in that teacher’s classroom. Additionally, van Es (2012) reported that teachers who watch video from classrooms other than their own could seem too distant from their practice, thus making it difficult for them to engage deeply enough to learn from the video. However, she goes on to caution that teachers who watch their own video struggle to engage in critical inquiry of their teaching and may be reluctant to share their video with other teachers for fear of criticism, resulting in a discourse that is “cordial and harmonious” (p. 184).

Researchers who used video in their professional development note the importance of establishing a supportive and safe environment (Borko et al. 2008; Frykholm, 1998; Grossman, Wineburg, & Woolworth, 2001; Little, 2002; Sherin & Han, 2002). Teachers can feel more threatened by sharing video of their teaching than by sharing artifacts such as lesson plans or student work (Borko et al. 2008). In order for teachers to take this risk, they must feel part of a safe and supportive environment. Borko and colleagues go on to argue that “professional development programs should seek to foster productive conversations in which teachers discuss issues directly related to their own teaching and their students learning” (p. 421). To accomplish this, professional development leaders need to help teachers establish trust, create norms for productive talk, promote discussions around teaching and learning and balance a respectful and critical analysis of teaching.

The role of the facilitator of the professional development is important to consider. van Es (2012) used data from a monthly video club to suggest a framework for exploring issues of teaching and learning in the classroom. The findings indicated that the facilitator was instrumental in keeping the discussion focused on the topic rather than on incidental aspects of a typical classroom. Additionally, the facilitator plays an important role in managing social interactions. Alf Coles (2013) studied the role of the facilitator in moving the discussion from evaluative to interpretive when using video. He used video collected over a five-year period from one secondary mathematics department. Four teachers agreed to have their lessons videotaped and participate in a video club. From his analysis, he concluded that teachers should only watch short (3 to 5 minute) clips of an episode and should immediately proceed into a discussion of agreeing about the details of the episode. Re-watching the clips is necessary if it is unclear what actually took place. Then he insists that it is necessary to move the conversations immediately to interpretations of the episode that are grounded in the agreed observation. At times, the facilitator has to refocus the discussion on the interpretive aspects of conversation. In his report, he outlined key dimensions of the role for facilitators. First, facilitators must select short video clips to allow reconstruction of events and to have an established purpose for showing a particular video clip. Second, facilitators must establish discourse norms. Coles suggested clearly establishing that participants should not engage in interpretive talk until the group has fully agreed on what they saw in the episode, known as the reconstruction phase. Third, facilitators must be aware that there is a critical decision as to when it is appropriate to re-watch video clips. Fourth, facilitators must be able to identify the critical point to move the discussion to the interpretive phase. Coles suggested that using a key phrase to set up this shift is helpful. His key phrase is "what were the teaching strategies that she was employing there" (p. 176). Finally, facilitators must move the conversation to the metacommenting phase. This phase is where participants engage in succinct articulation of an issue. Coles argued that metacommenting supports participants to focus on a purpose to work on their own teaching and planning.

Case study. Using case study as a way of gaining knowledge in teaching is an effective way for teachers to examine their practice and their students' mathematical thinking and understanding (Shulman, 1986; Sowder, 2007). However, the use of case study as a learning tool was limited to the profession of law and medicine until the early 1990s. In Shulman's (1986) seminal paper, he argued for the use of case study in education. He described cases as providing "knowledge of specific, well-documented, and richly described events" (p. 11). Case studies can be productive in professional development because a facilitator usually guides the discussion of the case studies in a professional development. The facilitator can influence the focus, progress, and outcome of the discussion. The facilitator can encourage the teachers to critically examine the case and challenge the assumptions and ideas of both the teachers in the case study and other teachers in the professional development (Sowder, 2007).

Case studies are important for teacher learning because they are descriptive in nature, they describe teaching practice and they are a text for teacher learning. Cases provide a teacher with an opportunity for critical analysis of teaching and learning, to discuss ideas with colleagues, to reflect on their own practice by comparing what happened in the case to their own classroom, and to extend their pedagogical content knowledge. Additionally, cases provide a way for teachers to engage in safe inquiry because they are analyzing a classroom that is not their own or one of their colleagues (Sowder, 2007).

According to Merseth (1996), studying cases helps teachers become more reflective of their own practice and offers them the opportunity to build multiple strategies for their own practice. Using case study as a method of professional development can foster changes in practice, beliefs, and awareness of student learning (Barnett & Friedman, 1997). Stein et al. (2009), state that teachers often do not know how to reflect on their own classroom practice. When they watch a video of their own teaching episode, they are confused and overwhelmed by the myriad of activity and interactions. Stein et al. (2009) argued that the study of cases could help teachers situate the abstract into a framework (the Mathematical Task Framework) and make comparisons with their practice. They go on to say that simply making a connection from a case to their own practice does not mean that connection transfers to their practice. When facilitators assist teachers in viewing the cases through the lens of the Mathematical Task Framework, teachers notice important cues in the instructional episode and they learn how to interpret those cues as influences on student learning.

Teacher Beliefs

Beliefs about mathematics teaching and pedagogy are hard to change even with interventions through professional development. However, research is increasingly examining the influence of teacher beliefs on teaching practice in the learning process (Cobb et al. 1991; Pajares, 1992; Philipp, 2007; Philipp et al. 2007; Wilson & Cooney, 2002). Even though curriculum reform might suggest new directions, like using high cognitive demand tasks, the implementation of these new directions depends, in part, on what teachers believe about mathematics teaching and the learning of mathematics. Reforming the instructional practices of many mathematics teachers can only be actualized if we understand teachers' beliefs, and how beliefs are related to practice (Cross, 2009).

Research on teacher beliefs suggests that teachers are crucial change agents in educational reforms, and that changing teacher beliefs is a precursor to changing their teaching practice (Ernest, 1989; Stipek, Givvin, Salmon, & MacGyvers, 2001; Thompson, 1992). Beliefs are personal, stable, and influential in determining how individuals frame problems and structure tasks (Rimm-Kaufman & Sawyer, 2004). Research points to ways in which teachers translate their knowledge of mathematics and pedagogy into practice through the filter of their beliefs (Manouchehri, 1997; Thompson, 1992). Teachers' instructional practice depends on what they believe the subject matter encompasses and how to teach it (Laurenson, 1995). The relationship between beliefs and practice is not one-directional (Guskey, 1986), and the connection between what teachers do and what teachers think is a complex relationship; what they do affects what they think and what they think affects what they do. Changing beliefs about instruction and classroom practice is a complex task (West & Staub, 2003). Thus, addressing teachers' beliefs in conjunction with engaging them in the implementation of new instructional practice, as well as providing a context for reflecting on those practices and revising beliefs, is imperative (Doerr & Lesh, 2003).

Enhancing Teacher Knowledge

Effectively implementing mathematical tasks in the classroom requires teachers to have a certain amount of mathematical content knowledge and pedagogical content knowledge. Teachers need both of these because they need to know what prior knowledge their students have so they can choose an appropriate task and they need to know how to scaffold the task for students without crossing the line of lowering the cognitive demand of the task. Additionally, they need to recognize various mathematical strategies a student might use to solve the problem and how to facilitate mathematical discourse that delves into deeper mathematical understanding. Research indicates that too few teachers have the mathematical knowledge required to implement high cognitive demand tasks effectively in the classroom (Borko & Putnam, 1995).

Ball and Bass (2000) defined teachers' conceptual understanding of mathematics as mathematical content knowledge for teaching. This differs from pedagogical content knowledge (Shulman, 1986) because it does not include effective ways to teach mathematics. Pedagogical content knowledge is used to describe the content and teaching knowledge that is necessary to teach the content effectively. It combines the subject matter with pedagogy to create the knowledge necessary to be an effective teacher of mathematics. Mathematical content knowledge is the specific content knowledge that elementary teachers need to understand so they may effectively instruct students (Hill & Ball, 2004). This involves a deep understanding of various representations of problems, numbers, and concepts. It also requires an understanding of the relationships between various mathematical topics. Ma (1999) described this knowledge of mathematics as flexibility in grasping multiple perspectives and understanding the connection of mathematical ideas. Elementary teachers need to have a comprehensive knowledge of specific mathematical ideas in order to plan instruction, evaluate student understanding, and explain mathematical concepts. Teachers need to have a deep understanding of multiple representation and mathematical concepts and an ability to recognize various problem-solving strategies. Teachers need the ability to hear and guide individual students through mathematical situations flexibly and with understanding of their diverse needs (Ball & Bass, 2000).

Sowder (2007) cites Grossman (1990) who described four central components of pedagogical content knowledge. The four components are (a) an overarching knowledge and belief about the purpose for teaching (b) knowledge about student understanding, conceptions, and potential misunderstandings (c) knowledge of curriculum and curricular materials (d) knowledge of instructional strategies and representations for teaching a particular topic. Teachers who have a poor understanding of mathematics are unlikely to develop this type of knowledge. This is especially true when mathematics becomes more sophisticated and requires multiple strategies and representations in order to meet specific goals for learning. The lack of content knowledge becomes problematic when teachers try to change their instruction through their existing knowledge. Limited content knowledge can lead to missed opportunities for making mathematical connections between concepts and representations (Sowder, 2007).

Chapter Summary

This chapter provided a view of the current literature on selecting and implementing high cognitive demand tasks in the classroom. Research on the type of mathematical tasks that elicit the most students' learning began with Doyle (1983). Doyle's contribution to the literature on mathematical tasks is that the type of task a student engages in directly correlates to how much a student learns. Silver and Stein

(1996) built on Doyle's research and subsequently their research through the QUASAR project launched a deeper understanding of the value of mathematical tasks and how to design professional development that is successful in changing teaching practice. Using high cognitive demand tasks in the classroom provides students with opportunities to make mathematical connections and reason, which are skills highly valued in the reform of mathematics education.

This chapter also provided a summary of the professional development literature that informs this investigation. Research surrounding the ideas of professional development to elicit change in teaching practice reveals that professional development must be on going, collaborative, based on constructivist theories of learning, and require teachers to reflect on their own practice. Professional development leaders can achieve these goals with case studies and video. As teachers have opportunity to view their own teaching and read case studies of the struggles other teachers encountered, they have opportunity to reflect on their own teaching. Structuring professional development within an environment where teachers collaborate with their peers creates learning environments where teachers can feel safe to express their successes and challenges of their classroom practice. Loucks-Horsley et al. (2010) argued that professional development must be transformative. This type of professional development helps teachers see the value in reform and they become willing to examine and reevaluate their long-held beliefs about teaching.

This research informed the current investigation by supporting teachers as they learned and reflected on the value of selecting and implementing high cognitive demand tasks in their classroom. The teachers learned how to identify a high cognitive demand task, how to use these tasks in their classroom maintaining the cognitive demand and reflected on their current teaching practice and the long-term value of using high cognitive demand tasks in their classroom.

CHAPTER THREE

Participants and Setting

This investigation took place in a suburban county in the mid-Atlantic region. The participants were 7 primary (K-2) elementary school teachers. There were six-second grade teachers and one kindergarten teacher. Their teaching experience ranged from 3 to 21 years. Three teachers had a bachelor degree, one teacher was National Board Certified, and three teachers had other endorsements to their teaching license such as reading specialist, special education, and middle school English. Most of the teaching experience of these teachers was in primary grades (K-2) although two teachers had experience in third and fourth grades. One teacher had a greater amount of experience in fifth grade than in primary (K-2). The pseudonyms of the teachers are: Hilary, Jill, Abby, Nikki, Victoria, Lily, and Phyllis.

I chose the school because I currently work as a math specialist there and keeping the participants for this study in one location ensured a shared context of what the teachers were doing in their classrooms on a regular basis. Other schools in this district may not be concentrating on how to improve teaching practice and student thinking in the same way and thus this would limit the shared knowledge and camaraderie. Additionally, the design of the professional development was based on learning communities, which requires a level of trust among the members (Wenger, 1998).

Opening this investigation to teachers in other schools could have hindered the comfortableness of the teachers to speak openly. Therefore, this was a purposeful sample. The elementary school where this investigation took place was a Title I school with about 40% of students qualifying for free and reduced lunch. Additionally, around 40% of the students were of Hispanic origin and about the same percent were English language learners.

After receiving approval to conduct this study (see Appendix A), I recruited the participants for the study by sending an email to every teacher in the school who taught kindergarten, first and second grades (see Appendix B). I told them if they were interested in participating in the study to attend an information session. I told them the place, date and time of the information session. At the information session, I explained the study and the requirements they were asked to fulfill. The teachers who agreed to participate signed the consent form at this meeting (see Appendix C).

Researcher Identity

I am a mathematics specialist at the elementary school where the study took place. My interest in becoming a math specialist stemmed from a disappointment in my life. I attended school in a small, rural town. The school did not have many resources to teach children beyond a basic education, and I was taught in a traditional fashion where rote memorization was valued. I felt as though the goal of my high school was to graduate students to become farmers, homemakers or secretaries. Although they promoted going to college, the school did not have the resources to prepare students adequately to attend college and embark on a professional career such as a physician. A physician was what I thought I wanted to be and I took all of the math and science classes my high school offered. When I started college, I noticed that I was not as knowledgeable as others were and I began to struggle. I talked with my advisor and he pointed out that I was educated in a small, rural town that did not offer advanced classes in mathematics or science, which in his opinion limited my ability to apply my knowledge. He informed me that the other students that I was comparing myself to had more opportunities to prepare themselves for the rigor of a premedical student. This made me angry. I was appalled that people who lived in large cities got a better education than I, and I had a hard time understanding this atrocity. As I look back and remember how I felt then, I am not convinced that I ever really made peace with this fact of my life. This event shaped who I am today and led me down the path to where I am now.

Instead of studying in another field of medicine I decided to abandon it entirely. I had come to believe that if I was not smart enough to be a physician then the medical field did not need me. I studied industrial technology and business; and, at the time, felt I would enjoy this career. It was not long before I realized I did not enjoy a career where I did not feel like I made a difference in the world. I continued to think about how if I had received a decent education I could be in a career where I helped others in need. I continued down this path until I literally reached a breaking point and I quit my job without notice and without another job.

Then I decided I wanted to change careers and become an elementary school teacher. I decided that I was going to teach my students math and science in a way that they could understand the concepts and give them opportunities to apply what they were learning. This was easy to say but hard to do. I sought all opportunities to learn to become a better math and science teacher. There were more opportunities for math so I followed that path. I became a math lead teacher at my school, and I became a member of a cohort of other teachers who were studying to become a math specialist. It was through these studies and my desire to "save the world" that I developed deep beliefs about how math should be taught.

I believe this passion was what fueled my desire to conduct research and to work with teachers on how to become better teachers of mathematics. We need children in our world that can think critically and solve complex problems, and we cannot move children toward that goal if they do not have opportunities to think deeply about mathematics. After all, I do not want another child to have their dreams squashed because they received a sub-par education. I understand how my past and present circumstances influence how I might look for evidence that is not there and how my emotions might sway this study. I know that my view about how math should be taught can limit the lenses I use when collecting and analyzing data. I know that for this study I am the researcher, not the math specialist, and I need to keep a close eye on my reformer attitude so I can authentically investigate. However, I also understand that it is these very emotions and passion that benefit me during this study. This reflection helped me monitor my thoughts and reactions so I could know when I was deviating off course.

Pilot Study

I conducted a pilot study in the fall of 2013 in preparation for this dissertation (Hargrove, 2013). The purpose of the study was to explore the ways in which teachers selected and implemented high cognitive demand tasks in their classrooms. This project used and extended a body of research focused on using high cognitive demand mathematics tasks as a means to enhance mathematics teaching and learning in ways that are consistent with current calls for 21st century learning and ensuring that students are prepared for college or the work force upon graduation from high school. The research questions were:

1. What factors influenced teachers to identify mathematical tasks as high cognitive demand?
2. How did teachers implement high cognitive demand tasks and maintain a high level of demand that supported student engagement throughout the instructional episode?

The research was a qualitative study, and the intent was to explore how elementary teachers' selected and implemented mathematical performance tasks in the classroom. The teachers participated in a task-sorting interview, and they implemented a mathematical task in their classroom. I used twenty mathematical tasks and asked them to sort the tasks in whatever way made sense to them, and designate the tasks as high cognitive demand or low cognitive demand. The teachers implemented a high cognitive demand task in their classroom. There were no specific instructions on how to implement the task and they were free to decide the best ways to use the task in their classroom. Although this pilot study was a qualitative study, I used quantitative instruments for the video-recorded classroom implementation to practice the use of these instruments before the data collection phase of my dissertation. The quantitative instruments did not influence the results of this study.

The participants were four teachers who work in the school where I am a math specialist. At the time of the study, one teacher taught third grade and was in her third year of teaching. She had only taught third grade and had a master's degree in elementary education. Three teachers taught fourth grade; of these, one teacher was in her second year of teaching, one was in her tenth year of teaching and the other had taught more than 15 years. All of the fourth grade teachers had master's degrees in elementary education. They had taught either third, fourth, fifth or sixth grade in their careers. The pilot study took place in a Title I elementary school. Two of the teachers taught an ESOL (English Speakers of Other Languages) class, and the other two teachers taught a Special Education (SPED) class. Both types of classrooms were inclusive classrooms, however, only one classroom had an ESOL teacher in the room and one classroom had a SPED teacher in the room during the lesson that was video recorded in this study.

The data collection used to answer the first research question was a task-sorting interview. I used the task sorting cards as an instrument to collect data to understand how teachers identify high and low cognitive demand mathematical tasks. Originally, the task sorting activity, created by the QUASAR project (Henningsen & Stein, 1997; Stein, et al. 1996) was used as a learning tool. Arbaugh and Brown (2005) used the task sorting activity as a data collection instrument to study how teachers' thinking about mathematical tasks changed over the course of the study. The purpose of the task-sorting interview was to understand how teachers identified mathematical tasks and what factors they used to determine if a mathematical task was high or low cognitive demand. The teachers completed the interview individually with me. The teachers were provided twenty cards containing a mathematical performance task and were asked to sort them into categories of their choice and to rank the tasks as high cognitive demand, low cognitive demand or not sure. After the teachers finished sorting the cards, I asked the teachers to describe the categories they created and to explain their criteria for rating the task as high or low. The task sort interview was audio recorded.

Next, to answer the second research question, I provided each teacher with a high cognitive demand mathematical task to implement in her classroom. The fourth grade teachers received the same task and the third grade teacher received a different task. The observations were video recorded for later analysis. The purpose of the lesson observation was to provide indicators of the classroom practice of the teachers with respect to the implementation of high cognitive demand tasks. The observation was for the entire math period.

I coded the qualitative data for the task sort and the task implementation using a constant comparative, thematic analysis approach (Glesne, 2011). The constant comparative analysis method is an iterative and inductive process of reducing the data through constant recoding (Glaser & Strauss, 1967). Data is compared to other data during the process of coding. This process begins with open coding to develop categories from the first round of data reduction and further reducing and recoding allows possible core categories or themes to emerge (Glaser & Strauss, 1967). According to Glesne

(2011), data analysis should happen nearly simultaneously with collection; therefore, I was coding the data throughout the investigation. All of the data were open coded looking for keywords or common language. According to Glesne (2011), this line-by-line coding helps immerse the researcher into the data and thus the researcher can discover the concepts. Next, I took the open codes and created a chart to record any themes that initially emerged from the open coding. Glesne (2011) recommends this type of thematic analysis when coding diverse datasets. Then, I reflected on the open codes and the initial themes and used selective coding to identify high-level themes. Finally, I classified the codes into larger themes and looked for any collapsible themes. I fully transcribed the audiotapes and coded the transcriptions by taking the open codes and identifying themes that emerged from the data. Then I reflected on the initial themes and identified higher-level themes.

The results of the pilot study were consistent with prior research on the identification and implementation of tasks. The teachers identified the tasks as high cognitive or low cognitive demand based on surface characteristics and content within the task. I collapsed the teacher created categories into five larger themes, which revealed that the teachers sorted the tasks based on content, surface characteristics, what students had to do to complete the task, what students had to do to answer the task (the end result), and categories based on student groups (English language learners and special education). The category most frequently used in the sort was surface characteristics. In other words, most of the teachers sorted the tasks based on the surface characteristic of the task. The implementation of the task in the classroom revealed the same results as prior research.

All four of the teachers lowered the cognitive demand of the task in some way. One teacher modeled a similar problem and posted the four ways to solve the problem on the wall. The problem that she modeled was too similar to the task she gave the students and most of them realized that and began to copy one of the examples on the wall. Two teachers did not give enough time for the students to explore or solve the task. Another teacher reduced the task to getting the right answer and did not spend any time talking with the students about how they thought about the problem.

This study did not have a professional development intervention. Since the teachers in the pilot study had difficulty selecting and implementing high cognitive demand tasks, I hypothesized that professional development might help them recognize high cognitive demand tasks and teach them to implement the tasks in a way that maintained the cognitive demand. Prior research points to the need to include professional development when teachers are learning about high cognitive demand tasks, and I knew I would need to design professional development that was ongoing and provided support for the teachers as they began to grapple with cognitive demand. Additionally, I learned from the pilot study that conducting an open interview is not easy and I needed to have a few common questions to ask, like "What about using manipulatives makes this task high cognitive?" I knew I would have to press the teachers to explain why the task is high or low cognitive because the teachers in the pilot study did not know how to talk about the thinking or reasoning the task had the potential to elicit. Finally, I learned that scaffolding would be an area that I needed to address in the professional development. The teachers referred to modeling the problem for their students as scaffolding. However, scaffolding a task is a way to support students' thinking without compromising the integrity of the task.

Data Sources

To answer the first research question for the dissertation, I used a set of mathematical tasks that would be appropriate for primary elementary grades. The first research question was, did these primary teachers' understanding of what constitutes a high cognitive demand task change after participating in professional development focused on selecting and implementing high cognitive demand tasks, and if so, how and why? I created a set of 40 mathematical tasks that were appropriate for primary elementary (grades K-2) mathematics classrooms (Hargrove, 2013) that covered six content areas: geometry, measurement, fractions, number and number sense, computation, and patterns. I created some of the tasks and others I found on the internet (see Appendix D for a copy of the tasks). The mathematical tasks span the four cognitive demand levels described by Stein et al. (2009). Initially, I created a set of tasks that contained 9 tasks that I identified as *Doing Mathematics*, 12 tasks each for *Procedures with Connections* and *Procedures without Connections*, and 7 tasks that I identified as *Memorization*. Four experts, three mathematics education doctoral students and one professor of mathematics education, independently classified all 40 tasks. Of the 40 tasks, there were initial disagreements between the experts and me on ten tasks. After discussion, we reached agreement on all 40 tasks. The final card sort contained 10 *Doing Mathematics*, 14 *Procedures with Connections*, 9 *Procedures without Connections*, and 7 *Memorization*. For the purposes of this investigation, I used 20 tasks as the pre and post task sort. I used the remaining 20 tasks in the professional development for the teachers to sort as they learned to identify the cognitive demand of tasks. The 20 tasks that I used in the pre and post task sort contained 5 *Doing Mathematics*, 8 *Procedures with Connections*, 4 *Procedure without Connections*, and 3 *Memorization*. The 20 tasks that I used in the professional development contained 5 *Doing Mathematics*, 6 *Procedures with Connections*, 5 *Procedures without Connections*, and 4 *Memorization*.

Next, I will discuss the data sources that I used to evaluate the classroom practice. Classroom practice was comprised of the collection of the tasks that the teacher used in the classroom, a sample set of student work, and the classroom observations. I used the Instructional Quality Assessment (IQA) in mathematics rubrics as instruments for all the data collected under classroom practice. Matsumura, Garnier, Slater, and Boston (2008) created and validated these instruments. I received permission from Dr. Melissa Boston via email to use these rubrics for my dissertation. Dr. Boston was explicit in mentioning that these rubrics were for my dissertation only and not to be shared with anyone other than those rating my dissertation data. Therefore, the IQA rubrics do not appear in the appendices of this dissertation. For the tasks teachers use in the classroom, I used the Potential of the Task rubric. For the collection of student work, I used the Implementation rubric. These two rubrics assessed the academic rigor of classroom assignments and served to answer research question number two. Refer to Table 1 for a description of the instruments.

There were several instruments that I used for the classroom observation. I used two criteria to assess the classroom observation. The first criterion was academic rigor of the lesson. The rubrics for that criterion were Potential of the Task and Implementation of the Task. Additionally, I used the Student Discussion Following the Task rubric, the Questioning rubric and the Mathematical Residue rubric. The second criterion was the rigor associated with quality talk during the lesson, called accountable talk. The rubrics for that criterion were Participation, Teacher and Student Linking and Teacher and Student Press. All of these rubrics served to answer research question number 3. I conducted a brief pre and post observation interview with each teacher. This interview serves as additional information to help score the rubrics accurately. See Appendix E for the protocol.

Table 1

Description of Rubrics to Measure Classroom Practice

Rubric	Scale	Description
Potential of the Task	0 - 4	What potential did the task have to engage students in rigorous thinking? The rubric measures if the task engages students in understanding mathematical concepts, procedures and/or relationships. If so, then at what level; strictly regurgitating facts, engaging in procedures or engages students in complex thinking.
Implementation of the Task	0 - 4	How did the teacher guide students to engage with the task? The rubric measures if the teacher guided the students' to engage in understanding mathematical concepts, procedures and/or relationships. If so, then at what level; students are strictly regurgitating facts, students are engaging in procedures or students are engaged in complex thinking.
Student Discussion	0 - 4	How did the student show their work and explain their thinking about the mathematical content? This rubric measures if the students provide thorough explanations of their solution, strategies, and connections to underlying mathematical ideas. If so, then at what level; students provide one word answers, students show one strategy or

		representation or students engage in meaningful mathematics discussion exploring the important mathematics in the task.
Questioning	0 - 4	To what extent does the teacher ask probing questions? At what level does the teacher engage in this type of questioning? Does the teacher ask questions that enable the student to elaborate their own thinking? Does the teacher ask factual questions or superficial questions?
Mathematical Residue	0 - 4	To what extent did the whole group discussion build new, important mathematical ideas? At what level; mathematical ideas do not surface, the teacher makes the mathematical ideas explicit, or the students' wrestle with the mathematical ideas presented and the discussion leaves behind important mathematical residue.
Teacher's Linking	0 - 4	Does the teacher support the students in connecting ideas? If so, at what level; there is no discussion, teacher re-voices the students' contribution or the teacher explicitly makes the connections.
Students' Linking	0 - 4	Do the students' contributions link to each other? If so, at what level; students do not link contributions, students sometimes links contribution, or students consistently link contributions.
Teacher Press	0 - 4	Were students pressed to support their contributions? If so, at what level; no effort to provide evidence, teacher asks for procedural knowledge, teacher always asks students to provide evidence.
Student Responses	0 - 4	To what extent do students support their contribution with evidence? They do not provide evidence, the provide procedural evidence, they explain their thinking using evidence and reasoning.

At the conclusion of this study, I conducted a brief interview with the teachers. The purpose of this interview was to determine what influences this study had on their teaching, to identify any barriers to using high cognitive demand tasks in the classroom regularly, and to assess their overall learning experience from the study and the professional development (see Appendix F for the protocol).

Research Design

This was a mixed methods study utilizing a quantitative pre- post design to determine any changes in how the teachers identified and implemented high cognitive demand tasks. Qualitative methods described the process of the changes in the teachers understanding of identifying and implementing high cognitive demand tasks. My reasons for choosing a mixed method design were twofold. The first reason is what Greene (2007) calls a purpose of complementarity. Prior research, from secondary schools, suggests that when teachers participated in professional development, most learned to identify and implement high cognitive demand tasks in the classroom and, for the most part, maintain the cognitive demand, and this study was no different. However, through this investigation, I sought a deeper, more comprehensive understanding of why the change took place. I sought to know more about the process of that change for primary teachers; what specifically about the professional development helped them understand what cognitive demand was and how to maintain it in the classroom. Secondly, I sought to discover what, if any, barriers primary teachers see to using high cognitive demand tasks in their classroom regularly.

Professional Development

There were three professional development sessions for this study. One took place in early September, another in late October and the last one in mid-November. See Appendix G for a list of what the teachers did during the professional development. The professional development design was based on learning communities. Drawing from Wenger's (1998) social theory of learning, the primary focus was on learning as social participation where the participants were actively engaged in the process of social community and constructing identities in relation to the communities. The duration of each professional development session was seven and a half hours. During this time, the teachers engaged in communicating their thoughts, struggles, passion, triumphs, and fears. They watched video of other teachers using high cognitive demand tasks and they discussed how they thought it would look in their own classroom. The teachers sorted tasks and talked about why they thought the tasks were high or low cognitive and they relied on each other to clarify their own thinking. They also looked at student work samples and read articles about high cognitive demand tasks as well as case studies of others using these tasks. The teachers expressed how they appreciated the time to communicate and internalize what they were learning.

All three professional developments were video recorded. I took research notes throughout the professional development and made notes about any critical incidents where the teachers were struggling to understand and where they had "aha" moments. I collected reflection sheets from them after each professional development and at the end of the study I interviewed them about their experience. Throughout the professional development, I continually asked the teachers what they thought about the sharing out part of using high cognitive tasks in the classroom and how they felt that looked with primary children. I asked them how they felt about allowing students to struggle and what they felt was the hardest part about using tasks in the classroom. The purpose of these questions was to gain deeper insights into what the teachers thought were the barriers or benefits to using these tasks in primary grades.

Data Collection

To answer the first research question, I used an interview including a task sort. The first research question was, did these primary teachers' understanding of what constitutes a high cognitive demand task change after participating in professional development focused on selecting and implementing high cognitive demand tasks, and if so, how and why? Before the first professional development, I met with the teachers individually to complete the pre- task sort interview. I gave the teachers a set of 20 tasks and a piece of chart paper and asked them to sort the tasks into two piles, high cognitive demand and low cognitive demand, on the chart paper. After they finished that, I asked them to sort the pile they categorized as high cognitive demand into categories that would help me better understand why they thought the tasks were high cognitive and to do the same with the tasks they sorted as low cognitive demand. Then I asked them to label the sorts. Next, I began recording an unstructured or conversational interview (Glesne, 2011). The interview questions "developed on the spot through dialogue and interactions with only the context of the research leading the way" (Glesne, 2011, p.102). This interview was unstructured because the questions I asked them depended upon how they sorted the tasks. However, I focused my questions on pressing the teachers to provide reasons for why they thought the tasks were high or low cognitive. I asked them what it was about the category they created that meant the task was high or low. For example, if a teacher said the tasks were high because the tasks required multiple solutions, then I would ask them what it is about requiring multiple solutions that makes the task high. I tried to ask questions that would get the teachers to focus on the thinking, connections or reasoning the task had the potential to elicit. After the final professional development and classroom observation, I met with the teachers, individually, to repeat this exact process using the same 20 tasks. This served as the post-task sort interview.

To answer the second research question, I asked the teachers to submit four mathematical tasks that they thought were high cognitive and engaged students in problem-solving activities. The second research question was, did these primary teachers maintain academic rigor of classroom assignments when using mathematical tasks, and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why? I asked them to attach six samples of students' work to each of the tasks (Clare, 2000; Matsumura, Garnier, Pascal, Valdes, 2002). I asked them to submit tasks that they used over the course of a week of mathematics instruction. I asked the teachers to fill out a cover sheet that informed me of the time they spent on the task, what the purpose of the task was and the teacher's expectation of the task (see Appendix H). On each of the student work samples, I asked the teachers to mark the samples with an *H* if they felt the student contributed to the solving of the task in a high cognitive way and an *L* if they felt the student contributed to the solving of the task in a low cognitive way. I asked the teachers to submit these tasks after the first professional development and again after the third professional development. The first professional development occurred in early September. During this time, teachers are spending the majority of their time establishing routines in the classroom and reviewing mathematics content from the prior year. Waiting until after the first professional development to collect this pre data ensured that the teachers were teaching the grade level content and the students knew the routines of the classroom. The task collection piece of this investigation was random (i.e. the teachers did not know when I was going to ask for a collection of tasks).

To answer the third research question I conducted a pre- and post- classroom observation that was video recorded. The third research question was, did these primary teachers implement high cognitive demand tasks and maintain a high level of demand that supports student engagement throughout the instructional episode and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why? I recorded the entire lesson, from the launch to the end of the sharing out session. I took observation notes of what the teacher was doing, who was sharing out solutions or thinking, and how the students were engaging with the task. Prior to the lesson observation, I met briefly with the teacher to talk about her plans for the lesson and again after the lesson to talk about what she thought about the lesson. This interview was audio recorded. The purpose for this brief interview was to have a clear idea of what the teachers' goals for the lesson were and how she planned to execute the lesson. This information allowed the inter-rater reliability coders and me to understand better why the teacher may have chosen to make the decisions she did. This information helped when rating the teachers' maintenance of the cognitive demand during the instructional episode. Two doctoral students rated subsets of the observation data of the other six teachers by watching the video recordings. We discussed the differences in our coding and reach consensus. Again, the pre classroom observation occurred after the first professional development because this ensured that the teachers were teaching the grade level content and the students knew the routines of the classroom.

One teacher opted out of video recording. For her observations, another doctoral student and I observed her lesson together and her lesson was audio recorded. The doctoral student and I discussed what we saw, rated her implementation of the task separately, and then discussed our differences in the ratings. The audio recording was available if we had questions about what she said.

To answer the fourth research question, I conducted three professional development sessions. The fourth research question was, did the professional development influence how primary teachers select and implement performance tasks in their classrooms, and if so, how and why? The first was in early September, the second was in late October and the final session was in mid-November. All the professional development sessions were video recorded. The teachers participated in various activities such as sorting tasks, reading and discussing case studies, solving mathematical tasks, choosing high cognitive mathematical tasks to use in their classroom, and planning lessons. They filled out reflections on what they learned (see Appendix I). I collected these artifacts for later analysis. I took observation notes and specifically noted critical incidents that occurred during the professional development. After the final professional development session and the post-task sort, I interviewed the teachers to determine what influences this study had on their teaching, any barriers to using high cognitive demand tasks in the classroom regularly, and their overall learning experience from this study and the professional development. This semi-structured interview was audio recorded.

Additionally, there was one additional video recording of the teachers using a high cognitive demand task in the classroom. I recorded this lesson in its entirety but it was not used as a data collection piece, rather as a learning tool for the teachers. The purpose of this additional video recording was to allow the teacher to view it, analyze her own teaching and then partner with another teacher, and have that teacher analyze the lesson.

Data Analysis

To analyze the task sort interview, I created a chart for each teacher that details how she sorted the task. The chart shows which sort (pre or post), the category she created and if the task was high or low cognitive demand (see Table 2).

Table 2

Sorting Chart

Pre-Sort - Chuck	Tasks	
Category Name	High	Low
Word Problems – (1.1)	1, 3, 9, 14, 19	5, 4, 20
Use manipulatives – (1.2)	2. 6, 8, 10, 16	7, 11, 12, 13
Show your thinking – (1.3)	15, 17, 18	

I created this chart from the chart paper that the teachers used during the task sort interview. Note that in each category, I assigned each category a number. These numbers reference the interview transcripts. When the teacher talked about a specific category or why she thought the task was high or low demand, I placed the same number on the transcript. Then I cut and pasted the transcript to the chart under the category. Table 3 shows an example.

Table 3

Sorting Chart with Interview

Pre-Sort - Chuck		Tasks	
Category Name		High	Low
Word Problems – (1.1)		1, 3, 9, 14, 19	5, 4, 20
C:	These are all word problems		
D:	So your first group is word problems		
C:	Yes. I mean…most of the tasks are word problems…kind of…but these are Problems they have to solve…do you know what I mean?		

When the post sort was finished I began analyzing the pre and post charts separately first by individual teacher and then across all teachers. I repeated the same process to compare the pre and post interview data. First, using a constant comparative thematic analysis, I looked for patterns in the teacher created categories. Then, using the same process, I looked for themes in the interview data that could help explain why the teachers' created the categories, and to determine if the teachers' language about the tasks changed from pre to post collections. The constant comparative analysis method is an iterative and inductive process of reducing the data through constant recoding (Glaser & Strauss, 1967). Data is compared to other data during the process of coding. This process begins with open coding to develop categories from the first round of data reduction and further reducing and recoding allows possible core categories or themes to emerge (Glaser & Strauss, 1967). I looked for any themes to collapse into one larger theme. To analyze how teachers sorted the tasks as high or low cognitive demand I created another chart that shows the data from the pre and post sorts. Table 4 shows an example. Another doctoral student coded a subset of this data and we discussed our differences and agreed on the specific codes and themes.

Table 4

High – Low Sort Chart

		Chuck's Sorts	
Sort	Task	Correctly Placed	Incorrectly Placed
Pre-Sort	High Cognitive	1, 2, 3, 4,	5, 6, 7, 8, 9, 10
	Low Cognitive	11, 12, 13, 14, 15	16, 17, 18, 19, 20
Post-Sort	High Cognitive	1, 2, 3, 4, 5, 6, 7, 8	9, 10
	Low Cognitive	11, 12, 13, 14, 15, 16, 17, 18, 19	20

I analyzed the data for the classroom practice by using a Mann-Whitney U test. I chose to use nonparametric analysis because the rubrics that rated the classroom practice were designed using an ordinal scale. In other words, the ratings (0 – 4) were arranged in an order but the difference between the data values cannot be determined. Therefore, the Mann-Whitney U test was used to compare the differences in the mean rank scores between the data collections. I used this analysis to answer research questions two and three, which includes all the rubrics associated with classroom practice. Two doctoral students rated a subset of the classroom practice data. We discussed our differences in ratings and came to a consensus. The inter-rater reliability percent for the task collection and student work was 68% and for the classroom observation, it was 71%.

Throughout the professional development, I took observation notes of all the critical incidents that occurred during the sessions. I transcribed the video from the professional development based on the observation notes. In other words, I did not transcribe all the video in its entirety; rather I transcribed seminal parts of the video that highlighted a teacher's development or struggle with the ideas being discussed. All of the data from the professional development sessions and the interview at the end of this investigation was coded utilizing a constant comparative thematic analysis. All verbal exchanges and written artifacts were coded for changes in teachers' knowledge or instructional practice, development or struggles with new ideas related to the cognitive demand of tasks (selection and implementation) or reflection on an instructional episode. A doctoral student rated a subset of the data and we compared codes and reach consensus.

Inter-Rater Reliability

Two doctoral students coded and rated subsets of this data throughout this investigation. When they were coding qualitative data, they used a constant comparative thematic analysis. We, the doctoral students and I, coded the data separately and then we met and compared our codes and themes. We discussed any differences in coding and reached consensus on appropriate codes for the data. Rating the rubrics for the classroom observation was more difficult. I mentioned above that I received a packet of rubrics from Dr. Melissa Boston. Included with the packet of rubrics was a rater-training manual and videos. I gave both doctoral students a copy of the rater-training manual and a set of rubrics to read. We met in early September to watch the videos supplied by Dr. Melissa Boston and to practice rating the classroom observations. At the end of each video, we discussed how we rated what we saw. We discussed our differences in coding and continued to practice with different videos. Throughout the process, we were not more than one interval away in our scoring.

The inter rater reliability for the classroom observation from this study was 71%. Although this is an acceptable rating, I thought it would have been higher given that the coders and I went through the training provided by Dr. Boston. I think one factor that contributed to a lower rating is that the videos provided by Dr. Boston were middle school mathematics classes and it was relatively easy to score the teacher and student contribution from the video. It was more difficult to score the contributions when watching video of primary (K-2) lessons. It was difficult to judge if the students were generalizing and it was difficult to determine if the students were engaged in exploring the mathematics in the task or just solving a problem. We grappled with this most when the majority of the students solved the problem in the same way or if a student solved the problem that brought out a mathematical concept but the child did not know how to explain the conjecture or provide evidence for their reasoning. We were not convinced that this meant that the students were not contributing at a high level and that caused friction in how to rate the contribution.

There was no training for the task collection piece of this investigation. We talked about how to go about rating the task and the student work when I met with the doctoral students to give them a subset of the data. I told them how Dr. Melissa Boston described how she rated the task collection and student work in previous studies. They were to rate the task based on the framework from Stein, et al. (2009). Both doctoral students had studied this framework. I told them they were to rate the student work based on if they thought that the majority of the samples showed students contributing at a high level of thinking or a low level of thinking. As previously mentioned an inter rater reliability of 68% was achieved for the task collection and student work component. I believe that part of this low rating was due to there not being training for this part of the data collection. The coders and I struggled with looking at the student work and using the implementation rubric to score the contribution of the students. We often grappled with scores between 2 and 3 because most of the samples only showed one way to solve the problem and if the students showed more than one way there were no connections between the representations. It was also difficult to judge if students this young were engaging in procedures based on prior instruction or engaging in thinking and creating meaning for mathematical procedures.

Limitations

There were limitations to the generalizability of this study. One limitation was the sample size of this investigation. This investigation was conducted in one elementary school and results may not be generalized to another elementary school in the same district or in a rural or urban setting. Finally, because of the limited number of observations, collections of student work, and collections of tasks, this study merely provides a snapshot of instruction in each of the teachers' classrooms, and therefore, may not represent the typical instructional practices of individual teachers or of the group of teachers.

Validity

An important validity threat to this study was reactivity. This study took place in the school where I work as a math specialist. The teachers view me as a knowledgeable mathematics person and therefore my mere presence could intimidate them. I continued to remind them that there were no right or wrong answers to what we were grappling with during the professional developments and my purpose for doing the study was to find out how these tasks work in primary elementary settings. I felt that the teachers were fairly open and honest about their struggles and triumphs; however, one must acknowledge that they may have at times held back.

Researcher bias was another validity threat to this study. To counteract this I looked for data that provided evidence to my conclusions. Because of my background as a math specialist and my knowledge of high cognitive demand tasks, I believe that using these tasks in classrooms is an important instructional necessity. I identified this potential validity threat before beginning this study and I was careful not to impose my beliefs on the teachers in this study. Additionally, I kept a researcher journal to record notes that could point to biases. The use of inter-rater reliability checks helped to offset researcher bias.

Another validity threat was the lack of long-term involvement in this study. Throughout the analysis of this study, by constantly looking for evidence that pointed to change, and by using others to code and rate the data, I was able to discern when I was projecting change that was not actually present.

CHAPTER FOUR

In this chapter, the findings are organized based on the research questions presented in Chapter 1. Research question number one was addressed by describing the teachers' knowledge of high cognitive demand tasks and how their knowledge changed over time. The results of the pre- and post-task sort interview and a comparison of how the teachers sorted the tasks were used to describe the change in teacher knowledge. For the second research question, the focus is on how the teachers maintained academic rigor in the classroom through task selection and implementation of tasks throughout the study. This was examined through an analysis of the mean task scores at a high versus low level of cognitive demand from the pre- and post-data collections of student work. Next, the third research question was analyzed and addressed the implementation of the task through the classroom pre- and post-observation data. Finally, a description of the role the professional development played in the change in teacher selection and implementation of high cognitive demand tasks was examined.

Teachers' Knowledge of High Cognitive Demand Tasks

The results presented in this section pertain to Research Question 1:

Did these primary teachers' understanding of what constitutes a high cognitive demand task change after participating in professional development focused on selecting and implementing high cognitive demand tasks, and if so, how and why?

To answer this question, comparisons were made between the pre- and post-data task sort interview. The results of this comparison are presented in the remainder of this section.

The pre- and post- task sort interview served as an indicator of the teachers' knowledge of high cognitive demand tasks prior to and following their participation in professional development. All seven teachers participated in the pre- and post-task sort interview. In each interview, the teachers were asked to sort twenty tasks as either high cognitive or low cognitive demand. Then they were asked to sort the tasks they identified as high into categories that would help me understand why they thought those tasks were high. They were asked to do the same thing to the tasks they identified as low. They sorted these tasks on a large piece of chart paper. Then, I labeled the sorts with the categories the teachers created and I asked them questions about the sort. After the interview, I wrote the number of the task under each category (on the back of each task was a different number). I began analyzing this data by looking at the type of categories the teachers created in the pre and post sorts. The teachers created 20 categories from the pre-sort. Analysis of the post data revealed that the teachers created 19 categories. Using a constant comparative thematic analysis the categories were collapsed into three larger themes. Table 5 below shows the themes and a description of each theme.

Table 5

Categories and Themes from Task Sort Data

Pre-Sort		Post-Sort	
Theme	Teacher Created Category	Theme	Teacher Created Category
Service Characteristics	Multi-Step Explain your thinking Creative One Right Answer Simple Open ended Multiple Solutions Vocabulary Prior Knowledge Visual	Service Characteristics	Multi-Step Explain your thinking Creative One Right Answer Simple Open ended Multiple Solutions Prior Knowledge Visual
Content	Basic Pattern Basic Graph	Content	Basic Pattern Simple Addition Basic Fraction Story Problem
What students have to do to solve (process)	Use Manipulatives Fill in Answers Read Follow Directions Use Pictures Outside the Box Literal Comprehension No Computation	What students have to do to solve (process)	Skip Counting Counting Use Manipulatives Fill in Answers Read Use Pictures

Next, I coded the transcripts from the task sort interview. Again, I used a constant comparative thematic analysis. Another doctoral student also coded all of this data and then we crosschecked our analysis to arrive at consensus of the themes. The coding from the pre data was collapsed into two themes, hard and simple. If the teachers thought the task would be hard for their students to solve then they classified the task as high cognitive demand. If they thought the task would be easy for students they taught then the task was low cognitive demand. For example, Hilary said this to describe four tasks she identified as low cognitive;

> Hilary- On these ones they use manipulatives and pictures to help them do simple addition and subtraction and measurement problems.
>
> Researcher- What is it about using manipulatives that make it low instead of high?
>
> Hilary- I don't think it is the manipulatives that make it low, it is just the problems were simple and they were also using manipulatives for it.

In another example, Lily described why she felt two tasks were high cognitive demand. In this example, she described why the task was hard for kids; all the numbers confuse children.

> I feel like when some kids see different numbers they don't know which numbers to choose so they don't know how to categorize things. Like
> this one says they cost 5 cents and each one after costs 3 cents each they get confused by that. It is a lot of numbers and then it says 11 so they
> have to figure out which numbers to use first and which step to do with each number.

The post-task sort transcripts revealed a slight change in how the teachers were talking about the tasks. In the post-task sort, although the teachers still talked about the difficulty level of the task, they began to use the words thinking and reasoning more frequently in their descriptions. In this example, Abby was explaining why she thought one task was high cognitive. She talked about the reasoning and how the task was not about memorizing a basic fact, but the deeper understanding of what fact families mean and how fact families connect to other mathematics.

> I felt like it is reasoning just because they have to be able to..like it is not just like memorize 2 + 2 = 4. It is like this doesn't have to be a memorized fact in a fact family knowing like 8 – 3 = 5, it is the understanding that 8 – 5 would also help you if there were a missing addend or if they wanted to quickly come up with a solution, it is just a strategy on how they could solve an addition or subtraction problem.

When Lily was describing a task, she said, "They have to take their thinking from one thing to the next" and Phyllis said, "They have to think many different times, many different ways." It was evident from the comparison of the pre and post data that the teachers were beginning to identify tasks based on the thinking or reasoning the task had the potential to elicit. However, the majority of their explanations continued to be about the difficulty of the task.

I also analyzed the task sort data based on how the teachers correctly identified the tasks. As stated in Chapter 3, I created 40 tasks to use for this dissertation. Doctoral students, a professor of mathematics education and I rated the tasks as high cognitive

(*Doing Mathematics and Procedures with Connections*) or low cognitive (*Procedures without Connections and* Memorization). Using our rating of these tasks as a "key," I determined which tasks the teachers identified correctly. Based on this analysis, 5 teachers placed more tasks correctly in the post sort than the pre-sort. One teacher placed the same amount correctly from the pre to the post. Another teacher did not classify four tasks in the post sort and therefore, it appears that she did not place as many correct in the post sort. This provides further evidence that the teachers were beginning to make a shift in how they identified tasks, thus providing evidence that their knowledge of high cognitive demand tasks were changing. Table 6 shows the change in the percentage from pre to post for each teacher.

Table 6

Percentage Correct from Task Sort Data

Teacher	**Pre-Sort Percentage**	**Post Sort Percentage**
Jill	90%	70%
Victoria	75%	75%
Phyllis	65%	75%
Lily	75%	85%
Nikki	65%	75%
Abby	70%	75%
Hilary	75%	80%

Jill's score went down from the pre to the post because she refused to classify four tasks. She said that the tasks were mathematically low but since the tasks asked for an explanation that made it high and therefore, she was torn as to where to place the tasks. When Jill completed the pre-task sort, she placed three of four tasks that she refused to classify in the post-task sort correctly. In the pre-task sort, she classified one high task as low.

> I put these together because I think the hardest part is to explain. All of them say how do you know. That is really difficult or I found, like to articulate how they know or why that is the right answer…. Although I think like mathematically solving it isn't necessarily so difficult because they can make a choice but being able to use all of their cognitive ability to articulate why it is the right answer and explain is very difficult for them.

During the professional development sessions, Jill expressed that her students did not have the language acquisition to explain or verbally express how they reasoned through the task. Therefore, it was difficult for her to press the students to provide evidence, explaining the conceptual understandings and their reasoning. This seems to indicate that throughout the professional development sessions and throughout the implementation of high cognitive demand tasks, Jill has internalized that the critical point of optimal student learning comes from the implementation phase. Referring to the framework in chapter 1, Stein et al. (2009) suggest that the implementation phase influences the level and kind of student learning. Jill knows that in order to orchestrate that learning in her classroom, she must press her students to provide conceptual understanding, mathematical reasoning and connections. Given the age of her students and their level of language acquisition, she experiences children explaining their thinking to be so difficult that in her view it raises the cognitive demand of the task. It seems that what she was focusing on was that explaining was difficult for her students and therefore, that would make it high cognitive instead of identifying the mathematical understandings that could potentially come from the task itself and deciding if it was a high or low cognitive task. However, what was interesting was that, looking at the detailed analysis of how she classified the tasks (see Table J1 in Appendix J), if you just look at the ones she did classify it was evident that she placed the majority of the tasks correctly. In addition, the fact that she got 90% correct in the pre-task sort meant that she had little room to show improvement.

Another interesting point that can be seen from the detailed analysis was that all of the teachers over-identified the tasks as low cognitive demand. In other words, they correctly identified the high cognitive demand tasks and rarely identified a low cognitive task as high cognitive. They consistently did this in the pre and post task sorts. This was interesting to me because although the teachers continued to provide criteria for the task being high or low based on surface characteristics, content or what students have to do to solve the problem, they seemed to identify more correctly the high cognitive tasks. Perhaps this indicates that they did not have the vocabulary and/or content knowledge to describe the task based on the thinking the task could elicit, rather than they did not know how to identify high cognitive demand tasks. Additionally, this led me to believe that these teachers would choose a high cognitive task to use in their classrooms more often than a low cognitive task.

Several teachers identified two tasks as low cognitive when in fact the tasks were high cognitive. One of the tasks is shown in Figure 3 below.

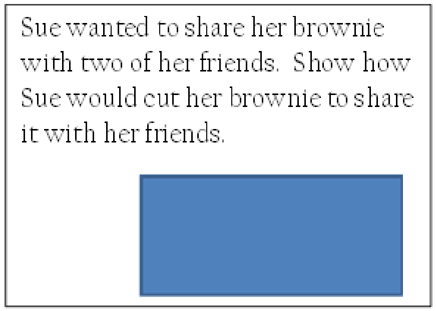


Figure 3. Brownie Task

Four teachers incorrectly identified this task as low cognitive. The four teachers who identified this task as low cognitive talked about how the visual was too much help because all the students had to do was divide the rectangle into thirds. Lily said, "I feel like the rectangle makes it too easy. If they had to draw the brownie and then divide it, that would make it harder." Nikki said, "All they have to do is draw two lines, as long as they understand that Sue and the friends get the brownie. It is just basic fraction stuff." In this task, the teachers identified the task based on surface characteristics, more specifically, "visuals." This common categorization was seen repeatedly through prior research. The teachers failed to realize the power in the fact that the brownie can be divided many different ways. When the students share out their work the teachers can lead the discussion to asking the children what fractional part of the brownie each child received, and then to discuss how they are all getting the same amount even though the brownie was divided into smaller pieces. For example, most students will draw two lines and show three equal pieces, but when asked to show it in as many different ways as they can think of they start to divide the brownie into smaller pieces. Therefore, each child could get one-third of the brownie or four-twelves of the brownie. Allowing the students to reason that the fractions are equal builds their understanding of equivalent fractions and it allows them to make connections to the relationship between the numerator and denominator. Incidentally, the three teachers who identified this task as high cognitive did so because the task had multiple solutions.

The second task that the four teachers incorrectly identified as low cognitive is shown in Figure 4. Those four teachers felt the task was easy if students drew a picture and the only thing that might hinder their ability to solve the task would be if they did not understand that the task was asking for the number of friends that got two cookies.

> Sally baked 12 cookies to share evenly with her friends. Each friend and Sally got 2 cookies. How many friends did Sally share her cookies with?

Figure 4. Cookie Task

Nikki said, “This one is relatively simple but it is hard for children to divide. It is really not that hard if they have manipulatives. Only division makes it hard.” Lily said, “This is just one answer. They don’t have to explain their thinking or anything.” In fact, this task can be solved in multiple ways. Most children think the answer is six but that can lead into a rich discussion about what the problem is asking. Then they have to think about how they can figure out how many friends Sally shared the cookies with from the way they solved the problem. Children will solve this task by drawing twelve cookies and then circle two cookies at a time. If they are asked to write an equation for their solution, they will write 2 + 2 + 2 + 2 + 2 + 2 = 12. Some will count by two (e.g. 2 Sally, 2 friend, 2 friend, 2 friend, 2 friend, 2 friend). Other children will draw a circle and put two dots to represent the cookies on a plate and count until they have twelve dots. Still others will write twelve and subtract two until they reach zero. Then they count how many times they subtracted two. Children in primary grades (K-2) do not think of this problem explicitly as division; instead, they rely on their prior knowledge of addition and subtraction (Carpenter, Fennema, Franke, Levi, & Empson, 1999). When students share out solutions of the problem, they make connections to addition and subtraction, which are deep concepts to consider in primary education. Facilitating a conversation about why some solved with addition and others solved with subtraction leads to the realization that they are opposite operations. Furthermore, this type of problem builds the foundation for the concepts of division.

The teachers failed to realize that this problem could be solved multiple ways and the implications of those student representations for student reasoning, making connections and thinking. It was likely that these teachers incorrectly identified these tasks because primary teachers rarely, if ever, use this type of problem in their classrooms. Without knowledge of the kind of thinking this task had the potential to elicit, they would not automatically identify this task as high cognitive. A teacher, Jill, who identified this task as high did so because, “They would need manipulatives to solve this problem.” Phyllis said, “The question changes and it is not about the number of cookies, it becomes about the friends. They have to pay attention to what the answer really is.” Hilary said, “It doesn’t give them all the numbers they need. It is just complicated.” These teachers did not identify this task as high because of the thinking the task could elicit; rather, they relied on the fact that they thought the problem was difficult. I found this result interesting because it made me question, again, how much content knowledge is needed for teachers to correctly identify high cognitive demand tasks.

The gains the teachers made in their ability to begin talking about the tasks from the perspective of thinking and reasoning and to increase the percentage of tasks sorted correctly can be attributed to the professional development. During the professional development sessions, the teachers practiced sorting mathematical tasks three separate times. At the end of each professional development, the teachers completed reflection sheets about their learning. One question asked them how their thinking about high cognitive demand tasks had changed. The teachers wrote about how they learned that if a task was difficult or hard it was not necessarily high cognitive and how the professional development had made them think more about what was actually high cognitive demand. Jill said, “High cognitive demands are not necessarily the most difficult tasks, but instead the tasks that require the most clever problem solving skills and thinking.” Nikki said the professional development was helping her in evolving her thinking and to look more critically at what she was having her students work on in class. She goes on to say that she was learning that "Analyzing the content and if it requires a higher level of cognitive thinking…" was the criterion that she would use in the future to evaluate the tasks she gives to her students.

Each of the professional development sessions was video recorded and a gradual change could be heard in how the teachers talked about the tasks. They stopped themselves when they said a task was hard and reminded themselves that "hard" did not mean high cognitive demand. They began to talk more about the kind of thinking or reasoning the task elicited. For example, Nikki said, "Well, this task is basic, I mean it is really simple, like…oh wait, that is not why I think it's low. It is low because they don't have to analyze the graph or really think about…you know." I conducted an interview at the end of this study and some of the teachers mentioned that they thought the task sorting was a big part of their learning. They admitted they still needed to work on identifying high cognitive demand tasks and they felt the time in the professional development help move them forward in their thinking.

Teachers' Maintaining Rigor of Classroom Assignments

The results presented in this section pertain to Research Question 2:

Did these primary teachers maintain academic rigor of classroom assignments when using mathematical tasks, and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?

To answer this question, comparisons of the tasks and the student work that were collected were analyzed by comparing the mean rank scores from the pre and post-task and student work collection. Findings from both types of analyses will be discussed in this section.

The teachers were asked to provide four tasks they thought were high cognitive demand and six samples of student work for each task that they used in their classroom during a given week. They were asked to fill out a cover sheet detailing what the task was used for, how much time they spent on the task, and their expectation for the task. They were to rate the student work as high if they felt the student contributed to the work at a high level and low if they felt the student did not contribute at a high level. The teachers were asked to provide this data two times during the study, the first time after the first professional development and the second time after the final professional development. The teachers were given a red folder to collect this data and they did not know when I would hand them the red folder and ask them for the tasks they did that week. I used two rubrics (*Potential of Task and Implementation)* to score the pre and post data. The Potential of Task rubric was rated by considering the highest level of cognitive processes required to produce a complete and thorough response to the task and the Implementation rubric was scored based on the highest level of students' engagement in mathematical work and thinking evident in the majority of student work samples (Boston, 2012). Two doctoral students rated a subset of the tasks and student work. We discussed our differences in coding and reached consensus. Five teachers provided all the tasks and work samples for the pre collection. One teacher provided only three tasks and one teacher provided four tasks but only had four work samples attached to one task (see Table K2 in Appendix K for a collected data and missing data table).

A Mann-Whitney U test was performed to compare the mean rank scores between the pre and post task collections. The Mann-Whitney U test indicated that the selection of high cognitive demand tasks was significantly greater for the post task (n = 28) collection (Mdn = 3) than for the pre task (n = 26) collection (Mdn = 3). U = 191.0, p = .001. Additionally, a Mann-Whitney U test was performed to compare the mean rank scores between the pre and post student work collections. The Mann-Whitney U test indicated that the implementation of high cognitive demand tasks was significantly greater for the post student work (n = 28) collection (Mdn = 3) than for the pre student work (n = 26) collection (Mdn = 2). U = 119.0, p = .001

The frequency table (see Table 7) provides additional evidence. Maintaining the academic rigor means the teachers were choosing high cognitive demand tasks and when they implemented them in their classroom the students engaged in complex thinking, or in creating meaning for mathematical concepts, procedures, and relationships (Boston, 2012). The teachers were making shifts to maintaining the academic rigor of classroom assignments as can be seen when comparing the pre and post scores. The frequency rating of three for implementation goes up from three to twenty-one when comparing pre to post.

Table 7

Frequency Distribution of Task Collection Data

Rating	PRE Potential	PRE Implementation	POST Potential	POST Implementation
0	0	0	0	0
1	4	4	0	0
2	8	19	4	7
3	14	3	17	21
4	0	0	7	0

Note. PRE = pre data collection after the first professional development (*n = 26*); POST = post data collection after the final professional development (*n = 28*).

The student work that was attached to the tasks showed students were identifying patterns, using multiple strategies to solve the tasks and making mathematical conjectures. The work did not receive a four because explicit evidence of reasoning was not evident on the majority of the samples. Additionally, the majority of the samples did not show that the students were making generalizations or mathematical connections. The student work samples received mostly two's in the pre collection because the students engaged in using a procedure based on prior instruction and the focus seemed to be on getting the correct answer rather than developing mathematical meaning.

Results from the Mann Whitney U test and the frequency table suggest that teacher growth occurred from the professional development as the teachers continued to sort tasks, consider the students' engagement in thinking from the work samples, and learn how to maintain cognitive demand throughout the instructional episode. In addition to sorting tasks and learning about maintaining cognitive demand when implementing the tasks during the professional development, the teachers looked at student work samples and they discussed how they could tell if the student was contributing to the task in a high cognitive way. They discussed what kind of thinking was appropriate at the primary level and what they would like to see children doing when they solve high cognitive mathematical tasks.

I asked the teachers to look at a sample set of student work from a Kindergarten class that was not included in this study. I asked them if they thought that the students' contribution to the task was low since they did not show multiple representations. The teachers did not think it meant a low contribution given the samples were from Kindergarten and in October. Victoria said she thought the contribution was high because "They were able to internalize the problem and show the eight red and four green balloons." Jill said, "I think we have to consider that Kindergartners don't know other strategies to solve problems right now." The teachers felt that most of the students contributed at a high level because the work showed thinking. However, Lily was grappling with the student work that did not have an answer or a correct answer. She said, "These are very clear on what they did, but there is no number and these have a number, the correct answer, but there is nothing to show how they got the answer." Lily was concerned that since there was no answer how would a teacher know if the student understood. In an effort to help the teachers understand, Jill informed them that many Kindergartners do not know how to write the number twelve so that might be why there was no number. Victoria was not bothered by the fact that the samples have no answer. She felt that since the work shows thinking and reasoning that meant something significant. Victoria said, "There is a lot of thinking going on here..a lot of erasing and rethinking. I think by what they show here they were showing a lot of reasoning and thinking." In another professional development session when the teachers were looking at student work Phyllis said, "I would have expected these to be low but it is apparent that these students were working hard and really thinking about how to solve this problem even though they did not get a correct answer." The other teachers agreed. This was a significant breakthrough, because now the teachers were looking at student work with the lens of the thinking and reasoning the child was contributing to the task and not just if the task had a correct answer. I asked the teachers to consider what they felt was a high level of student contribution in primary classrooms. They agreed that in primary classrooms high contribution means the students show how they thought about the task, show how they came up with the answer and how they show their mathematical understanding. These type of discussion challenged the teachers to not only look for a correct answer but more importantly to look at the way the student was thinking and reasoning about the task.

Teachers' Implementation of the Tasks

The results presented in this section pertain to Research Question 3:

Did these primary teachers implement high cognitive demand tasks and maintain a high level of demand that supports student engagement throughout the instructional episode and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?

To answer this question, comparisons of the classroom observation data were analyzed by comparing the mean rank scores from the pre and post-observation data. The results of this comparison are presented in the remainder of this section.

The teachers scheduled two observations with me. The pre observation was scheduled in October and the post observation was scheduled in December. For these observations, the teachers were asked to choose a task they thought was a high cognitive task and to use the task in their classroom. At the first professional development, before the pre observation, the teachers and I discussed the components of a successfully implemented task. At that time, we did not go into detail about how to launch the task, how to scaffold as students grappled with the task or how to orchestrate classroom discourse about the task. The classroom observations were video recorded and I took observation notes as well.

The teachers were scored on two criteria during the observation. The first criterion was how the teacher maintained academic rigor throughout the instructional episode. Academic rigor assessed how the teacher scaffolded the task for those who were struggling, the kind of questions she asked the students (procedural or probing), and how the students contributed to the process of solving the task and the type of discussions they had during the sharing out time. The second criterion was how the teacher promoted accountable talk. Accountable talk assessed how the teacher pressed the students for understanding, reasoning and connections. It also assessed how the teacher linked the thinking the student engaged in to other students' thinking or other areas in mathematics.

A Mann-Whitney U test was performed to compare the mean rank scores between the pre and post observations academic rigor. The Mann-Whitney U test indicated that the academic rigor of high cognitive demand tasks was significantly greater for the post data collection (*Mdn* = 2) than for the pre data collection (*Mdn* = 2). $U = 396.5$, $p = .006$. A Mann-Whitney U test was performed to compare the mean rank scores between the pre and post observations accountable talk. The Mann-Whitney U test indicated that the accountable talk of high cognitive demand tasks was significantly greater for the post data collection (*Mdn* = 2) than for the pre data collection (*Mdn* = 2). $U = 448.0$, $p = .037$.

The frequency table provided additional evidence that the teachers improved on maintaining the academic rigor throughout the instructional episode (see Table 8). Two areas showed the most growth: Implementation and Questioning. Implementation was the same criterion that was described in the above section on task collection. The only difference was that for the classroom observation I did not collect the student work. When the students were sent to work on the task, I wrote observation notes about how the students were solving the problem. From those notes and from what was videotaped of the sharing out I coded the student contribution to the task using the implementation rubric. During the pre-data collection, the students engaged in using a procedure based on prior instruction and the focus seemed to be on getting the correct answer rather than developing mathematical meaning. The post-data collection shows that students were identifying patterns, using multiple strategies to solve the tasks and making mathematical conjectures.

Table 8

Frequency Distribution of Task Implementation Academic Rigor

	Pre and (Post) at Each Score Level				
	Not Present	Low-Level Demand		High-Level Demand	
	0	1	2	3	4
Potential	0 (0)	0 (0)	1 (1)	6 (4)	0 (2)
Implementation	0 (0)	0 (0)	6 (1)	1 (6)	0 (0)
Student Discussion	0 (0)	1 (0)	6 (7)	0 (0)	0 (0)
Questioning	0 (0)	3 (1)	3 (2)	1 (4)	0 (0)
Mathematical Residue	0 (0)	6 (1)	1 (6)	0 (0)	0 (0)

Note. Pre = pre data collection after the first professional development (n = 7 teachers; 14 observations); Post = post data collection after the final professional development (n = 7 teachers; 14 observations).

Another area that showed growth was questioning. The teachers asked very few questions and did not probe the students to show mathematical meaning in the pre observation. They simply asked factual questions such as, “How do you know” or “How did you get your answer?” Although these two questions could be probing question, the context of these question during the pre-observation simply required the student to reply with a single response answer. Some of the teachers asked one probing question that had the potential to elicit mathematical thinking or developing mathematical understanding. For example, Lily asked a student how he kept track of his counting when solving the task. In the post observation, the teachers spent more time asking probing questions to elicit more student thinking and reasoning. They did this during the time the students were working on the task and sharing out their work. More than half of the teachers were asking probing questions, questions that would generate discussion, and questions that explored mathematical meaning. Some examples of these questions are, "Why did you choose to solve the problem this way?" or "How did counting by two's help you solve this problem?" The teachers were making a genuine effort to try to make connections between the students' strategies. They would ask, "Where do you see 27 in Student A and Student B's work?" or "How is Student A and Student B's work alike and different?" or "How did Student C use fact families to solve this problem?" These types of questions engaged the students to look more deeply at the actual thinking of another student. When the teachers were going around monitoring the students' work, when the students were solving the problem, they asked questions like "How are you thinking about this problem?" or "How could you show another way to solve this problem?" or "I see you're using patterns to solve this problem. How do you know when you've found all the possible solutions?" These questions probed the students to think more deeply about their own work.

The Accountable Talk frequency table provides evidence that the teachers improved in implementing high cognitive demand task (see Table 9). Two areas showed the most growth: Teacher Linking and Providing.

Table 9

Frequency Distribution of Task Implementation Accountable Talk

	Pre and (Post) at Each Score Level				
	Not Present	Low-Level Demand		High-Level Demand	
	0	1	2	3	4
Participation	0 (0)	4 (4)	2 (1)	0 (1)	1 (1)
Teacher Linking	0 (0)	1 (0)	5 (4)	1 (2)	0 (1)
Student Linking	0 (0)	7 (4)	0 (3)	0 (0)	0 (0)
Asking	0 (0)	1 (1)	5 (4)	1 (2)	0 (0)
Providing	0 (0)	4 (1)	3 (4)	0 (2)	0 (0)

Note. Pre = pre data collection after the first professional development (n = 7 teachers; 14 observations); Post = post data collection after the final professional development (n = 7 teachers; 14 observations).

Teacher linking assessed how the teacher supported students in connecting mathematical ideas to build coherence in the discussion. The frequency table shows that most of the teachers were at level two during the pre-observation. During this time, most of the teachers revoiced or recapped what the student shared but did not show how different students' ideas related to one another. Throughout the post observation, the teachers were trying to incorporate making connections during the sharing out portion of the lesson. Most of the teachers set a goal for themselves after the second and third professional development to make connections. Although about half of them were scored at level two, they were making one connection between the students' work but did not show how the ideas related. Three teachers were making two or more connections and were showing how they related to each other.

An area where there was little improvement was in student linking. For students to demonstrate that they were contributing at a high level they had to support their solutions with evidence or reasoning, giving conceptual explanations. This can be done by citing an example or referring to prior classroom experiences. Additionally, students had to connect their contributions to each other and show how ideas/positions shared during the discussion related to each other. In the professional development sessions, the teachers talked about how it was difficult to get children at this age to consider each other's thoughts because they are at the age where they are still very self-centered. They also talked about how difficult it was to get students of this age to sit long enough and pay attention to other students sharing ideas.

Results from the Mann Whitney U test and the frequency distribution tables suggest that teachers were able to maintain the cognitive demand of the task throughout the instructional episode and orchestrate productive discourse better after the three professional developments sessions. During the second professional development sessions, the teachers watched video of a teacher using high cognitive demand tasks in primary grades. They watched a teacher launch the task and then they discussed what they noticed about the launch. Then they watched a teacher monitoring students working, and they watched how to scaffold the task if students were struggling. In total, the teachers watched eight video clips of other teachers implementing high cognitive tasks in the classroom.

There was a lot of rich discussion from the teachers about what they saw. After they watched a launch episode, Nikki said, “It was good that the teacher read the task to the class and then had them read it together because it gets the kids focused and engaged and gets everyone on the same level to start. I think they really need that support.” Then the teachers talked about how they sometimes use students’ names in the problem to get them interested and how they could incorporate other things like making sure the students had an idea about how to get started with the problem. When the teachers were watching a video of how to get kids started when they are struggling, Hilary said she noticed, “The teacher gave him a lot of examples and other ways to think about the problem.” The other teachers commented on how the teacher did that but did not give away the problem. They also discussed how they thought the child in the video did not understand the problem and his inability to get started was not due to lack of math skills. They talked about how they see other students in the class struggle with problems and wondered if the children struggle because they did not understand the problem. One teacher, Phyllis, said that she would have encouraged the child in the video and let him know that he was on the right track and to keep talking about it and to keep thinking about it. This led into a conversation about what teachers can say to children to help them comprehend the problem. They talked about visualizing the problem first and then have the students begin working on the problem.

When they watched a video clip of a sharing out session where a teacher was specifically making connections between the students work they were intrigued about how the teacher orchestrated that with the students. They had not thought about the idea of making connections to other students work before when students were sharing out. In the reflections the teachers filled out at the end of this professional development, they wrote that one thing they were going to try to do differently was to work on having their students make connections to each other's works. Hilary wrote that she "plans to be more purposeful with the sharing and making connections." Nikki wrote that she would do the sharing piece "more purposefully by sequencing and having students make connections."

In the third professional development, the teachers watched video of themselves implementing a task. I gave them a viewing guide (see Appendix L) to help them focus on certain areas and not concentrate on analyzing their voice, hair or facial expressions. After they were finished viewing their own video, they paired up with another teacher and watched that teacher's video. Then they discussed what they noticed about each other's implementation of the task. When the teachers shared out what they learned, it was interesting that no one talked about what they noticed about themselves, rather they talked about what they noticed another teacher do that they wanted to incorporate in their next task implementation. One of the questions from the reflection sheet the teachers completed after this professional development session asked them what they learned from watching the video of themselves. The teachers wrote about how they needed to let the students talk more, that they do not have to give too much help; rather they can guide the students, that they needed to improve on helping students make more connections, and some set another goal to incorporate more quality talk. Some of the teachers said they appreciated watching the video of themselves and felt it was helpful for them to see what was really happening in their classroom. They felt they learned how to make changes to do better during the next task implementation. Incidentally, the teacher who opted out of being videotaped watched two videos of me implementing tasks in primary classrooms that were not included in this study. She and I discussed what we noticed from the two videos.

The Impact of the Professional Development

The results presented in this section pertain to Research Question 4: Did the professional development influence how primary teachers selected and implemented performance tasks in their classrooms, and if so, how and why?

To answer this question, qualitative data from the video of the professional development, the teachers' reflections after the professional development, and the interview were analyzed by utilizing a constant comparative thematic analysis. The results of this data are presented in the remainder of this section.

Using the data from the interview, the video of the professional development, and the teachers' reflections, I began line-by-line coding the responses to each question and the conversations from the professional development data, and placed those codes into sub-categories. Then I began further reducing the codes into emerging themes. Another doctoral student coded a subset of this data and then we crosschecked our analysis to arrive at consensus of the themes. The themes that emerged from the questions about the professional development were learning community, use of video, and accountability. The learning communities theme included ideas of the teachers learning because they were able to communicate with each other. They felt like they were able to internalize what they were learning, had many opportunities to discuss their thoughts and what worked, and did not work when using high cognitive demand tasks. They felt a sense of community with their grade level colleagues, and also the one teacher who was not a member of the same team, because they had open-ended, rich discussions. They felt encouraged and supported by their colleagues. Phyllis said, “We had time to think and talk, so that is where teachers can internalize because there was that time, gift of time.” Hilary talked about how this professional development helped her learn because, “We would share ideas and work together. You did a little bit at a time and gave us time to talk together and think.” Jill referred to this professional development as self-directed learning.

> We had a lot of time to reflect and we were given time to plan and we were given time to discuss. It was a lot of like self-directed in a lot of ways, like our learning. I think people learn a lot more from that type of learning than for just sitting and listening for 8 hours straight.

Throughout the professional development and from the interview data the teachers talked about how they appreciated the time to sit and think and to have others they could talk to about what they were learning. They felt as though there was a decrease in isolation and more time to learn from each other. The time gave them opportunities to ask questions and to talk with others about how to use these tasks in their classroom. They talked about how having a variety of perspectives, experiences, and opinions helped them feel like any issues they had when implementing tasks in their classroom was a shared problem because someone else was going through the same or similar struggle. Abby mentioned that what she most appreciated about the professional development was the structure;

> We were actively engaged in conversations a lot talking through things. It wasn't like 'this is what you're going to do and like this is why'. We were talking about what was working and what wasn't and how do we see it working in our classroom.

Other teachers talked about how the professional development was beneficial because they were ready for it and they volunteered instead of having the professional development forced upon them. They also talked about how they appreciated being treated as a professional. They appreciated that they got to make sense of the information and discuss how it could work in their classroom instead of being told how to do it.

Another theme that emerged from the data was that the teachers felt they learned a lot from this professional development because of the videos they watched. They felt the videos helped them see real teaching using high cognitive demand tasks. Having the real life examples showed them how to implement the tasks in their classroom and built their own confidence that they could use these tasks successfully. Phyllis expresses this best when she said:

> Like all the videos that we watched and looking at their population of their classroom and how they go about their methodology, how they have things set up and how when you see kids responding, then it makes you think it is possible. I like to see real life teaching.

In addition to watching video of other teachers, some of the teachers felt watching video of themselves and other teachers in the study was beneficial. Hilary mentioned that because of watching the videos of other teachers and teachers in the study she learned "strategies to use to set up a task and strategies to use to share and make connections during that share time." Throughout the professional development, the teachers were very engaged in watching the videos and talking about what they noticed and they asked many questions about what they saw.

Overall, the teachers felt the video in the professional development helped them learn to implement the tasks in their classroom. This was evident from the progress they made from the pre classroom observation and the post classroom observation. Watching video of other teachers showed them how to use mathematical tasks and maintain the cognitive demand. Teachers can read case studies and listen to a more knowledgeable other tell them how to implement tasks. However, when it was modeled for them in some way, like through the use of video, they felt more confident in their own ability. It no longer seemed impossible. When the teachers watched video of themselves, they got to see their own strengths and weaknesses. Additionally, when they watched the video of another teacher in this study they saw other strategies they had not used.

A final theme that emerged from the data was accountability. I define accountability as the immediate use of the new knowledge the teachers gained from the professional development in their classrooms. They did not have time to implement the new ideas a week later or never because they were going to be asked to give me tasks, student work samples and be observed. The teachers felt that the accountability of the professional development helped them use the tasks and practice what they were learning. Without the accountability, they said they would probably go back to their class with the intension of using the tasks but then may not have use them at all. Victoria had this to say about the accountability.

> I think being forced to practice to use the problem was most beneficial. Because it wasn't like we got it and that sounds great and then your off for a couple of weeks and then work gets in the way and you're just back to doing what you normally do. Having the deadlines of you have to do this, this week and knowing the red folders were coming. It kept it fresh. We just had to use it and we had to practice it.

Abby talks about how the professional development was different from others she had attended.

> I think like how it was broken up and we were able to learn and try something, learn and try something was really beneficial. Whereas other professional developments are just like 'okay here is all the information and like use this in your classroom one day' and then you're like 'okay I'm going to do that' and then

> school happens. I definitely feel like I was able to implement things I was learning from the professional development right away.

It is evident from the responses that the teachers gave that accountability is an important factor to consider when planning any professional development. The accountability allowed them to implement what they were learning so they could get better at using high cognitive demand tasks. Using new knowledge immediately ensures the best chance that teachers had an opportunity to grow in their own practice. Accountability brings to the forefront the need to have embedded school based professional development. This will allow the easiest way to include an accountability component.

Chapter Summary

These primary teachers were able to understand what constitutes a high cognitive demand task, maintain academic rigor of classroom assignments, implement high cognitive demand tasks and maintain high levels of demand after participating in professional development focused on selecting and implementing high cognitive demand tasks. The teachers' language when describing why a task was high cognitive or low cognitive changed from the pre- to post- sort interviews. During the pre-sort, the teachers described the tasks as high if they felt their students would have difficulty solving the task and they described the tasks as low if they felt their students would be able to solve the task easily. Although the teachers still talked about tasks being hard and easy in the post-sort, they began to use language associated with high cognitive demand principles such as thinking and reasoning.

Evidence of the teachers maintaining academic rigor of classroom assignments was clearly seen from the student work samples collected for the post collections. The student work from the post collection showed students were identifying patterns, using multiple strategies to solve the tasks and making mathematical conjectures. The student work samples received mostly two’s in the pre collection because the students engaged in using a procedure based on prior instruction and the focus seemed to be on getting the correct answer rather than developing mathematical meaning. The teachers were able to implement high cognitive demand tasks in their classroom and maintain the cognitive demand. During the pre-classroom observation, most of the teachers revoiced or recapped what the student shared but did not show how different students’ ideas related to one another. Throughout the post observation, the teachers tried to incorporate making connections during the sharing out portion of the lesson. Additionally, the teachers asked very few questions and did not probe the students to show mathematical meaning in the pre observation. Some of them asked one probing question that had the potential to elicit mathematical thinking or developing mathematical understanding. In the post observation, the teachers spent more time asking probing questions to elicit more student thinking and reasoning.

Three themes emerged to describe how the professional development influenced this change. The first theme was that the professional development was structured as a learning community where the teachers talked with each other and were able to internalize their learning and grapple with the new knowledge from the professional development. They felt the learning community allowed them to make sense of the information instead of being told what to do. The second theme was the use of video in the professional development. The teachers felt the video was an integral part of their learning. They reported that they felt watching video of other teachers not in this study helped them first see how to implement the tasks and this gave them confidence that they could implement high cognitive demand tasks. Then they said the video of watching themselves and other teachers in this study helped them notice where they were making mistakes when they compared themselves to video of other teachers both in this study and not in this study. They said they did not think they would have learned as much if they had just been told how to implement the tasks because the video gave them an example of using high cognitive demand tasks in the classroom. Finally, the third theme to the success of the professional development was accountability. The teachers felt that because they were responsible for using tasks in their classroom regularly they were able to implement the new knowledge from the professional development immediately, which resulted in their own personal learning.

CHAPTER FIVE

The purpose of this study was to better understand how primary elementary teachers selected and implemented high cognitive demand tasks in their classrooms and how professional development influenced this change. To accomplish this goal a mixed methods study was utilized to answer the following research questions:

1. Did these primary teachers' understanding of what constitutes a high cognitive demand task change after participating in professional development focused on selecting and implementing high cognitive demand tasks, and if so, how and why?
2. Did these primary teachers maintain academic rigor of classroom assignments when using mathematical tasks, and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?
3. Did these primary teachers implement high cognitive demand tasks and maintain a high level of demand that supports student engagement throughout the instructional episode and did this change during professional development focused on selecting and implementing high cognitive demand tasks, if so, how and why?
4. Did the professional development influence how primary teachers selected and implemented performance tasks in their classrooms, and if so, how and why?

Seven primary (K-2) teachers participated in this study. They agreed to participate in three, all day, professional development sessions. They agreed to do a pre and post task sort interview, submit tasks they used in their classroom with student work, to be observed using high cognitive demand tasks, and to be interviewed. This chapter provides a discussion of the findings and discusses the implications for research and education policy.

Discussion

Three themes or general conclusions emerged from the analysis of the data collected for the study: (a) as teachers are given numerous opportunities to implement new practices, their knowledge of and aptitude to implement high cognitive demand tasks change; (b) teachers' active participation in professional development and their own learning strongly influences teacher change; (c) professional development that is sustained and supported at the school level is paramount to successful implementation of new instructional practices. I provide an in-depth discussion of each of these themes below.

Opportunities to implement new practices. I discussed in chapter 4 that the teacher felt that one of the reasons they learned so much about selecting and implementing high cognitive demand tasks was because they were held accountable to the professional development. The teachers were required to use high cognitive demand tasks in their classroom immediately and further, they were required to use many tasks; not just one or two and then revert to the way they normally teach. This constant practice of using tasks allowed the teachers to experience what they learned in the professional development. In chapter 2, I outlined ways that Speck and Knipe (2001) believe that facilitators of professional development can support the adult learner. One way to support adult learners is to understand that they do not automatically transfer learning into their daily practice. They need coaching and support to sustain their efforts. After each implementation phase, we met as a group for another professional development. The teachers were given time to talk about what they experienced when they were implementing the tasks. In this way, the teachers felt supported and in control of their learning. When the teachers compared the professional development they received from the study to other professional development, they talked about how at other professional developments they are sometimes asked to try a new practice and then come back with evidence. What they felt was missing was being able to talk to other colleagues, especially colleagues they work with, about how the implementation went. They did not feel supported in discussing what did not go well or what concerns they had about using a new practice in their classroom. The professional development from this study allowed them to receive the support they needed to implement the tasks. Further, Loucks-Horsley et al. (2010) contend that in order for teachers to transform their practice they need multiple opportunities to learn, reflect and apply new practices. This study provided those multiple opportunities instead of trying a new behavior one time and then reporting on what was learned.

A large part of the teachers' learning came from experiencing all the phases of the mathematical task framework that was explained in chapter 1. The teachers were asked to select their own tasks, launch their own tasks and then implement those tasks in their classroom. This requirement took them through all the phases of the mathematical task framework. As the teachers were proceeding through all the phases of the framework, they had to consider what factors most influenced students thinking. The teachers had to consider their goal and the students' background knowledge when selecting and launching the task. They realized that they could not simply select any task and hope for success. They had to consider what norms were in place to convey the expectations of how mathematical work is done and what is the degree of quality. They had to consider the appropriateness of the task to meet their goal, the appropriateness of the task to the background knowledge of the students and the time they had during class for successful implementation of the task. The teachers had to consider their own pedagogical behaviors in relation to the task. In other words, how willing was she to let the students struggle and how could she scaffold the task to support student learning. As they had multiple opportunities to take a task through all the phases of the mathematical task framework, they began to understand that the implementation phase was very important. As they looked at the work their students were producing, they began to comment about how beneficial using tasks were because their students were able to apply the rote knowledge from prior instruction. Seeing student learning outcomes began to change any notions of the benefits of using high cognitive demand tasks; they began to believe in the value of using such tasks and were excited to see what their students could do. This supports what Guskey (2002) suggests, that teachers change when they see changes in student outcomes. In this study, the teachers were not given a task to implement, rather they had to take a task through all the phases of the framework and consider all the factors associated with the successful implementation of the task. This is one thing that increased their learning and understanding of how to select and implement high cognitive demand tasks in the classroom. Grant, Hiebert, and Wearne (1998) conclude that simply telling teachers about the benefits of using high cognitive demand tasks in the classroom is not enough. Teachers must experience how the new practice affects student understanding and how it affects their own teaching.

Active participation in professional development. The teachers in this study were not passive receivers of information; rather they were active participants in the professional development. The learning community design of the professional development fostered an environment where the teachers did not feel they were isolated. All of the second grade teachers have been part of a team for a few years (with the exception of two more recent additions) so they already established trust and commonality. The one kindergarten teacher quickly adjusted to the group and became a member of a trusted community of learners. Once this community was established, the teachers felt comfortable discussing the concepts of high cognitive demand tasks and processing how the tasks would fit in their classrooms. This type of reflection is what Wood and Bennett (2000) suggest as an effective model for professional development. This is because as teachers reflect they have time to question their own beliefs and practices in the classroom with other likeminded people in a supportive environment.

The learning community design allowed the teachers to take ownership of their learning. They guided most of the agenda of the professional development. When they needed to stop and discuss their learning or their concerns, they were given the liberty to do so. In this way, they were constructing their own understandings. The learning the teachers engaged in through this professional development was socially constructed rather than individual learning. The findings of this study suggest that teacher learning and change occurred because the teachers were engaged in learning communities, thus confirming findings from prior research (Fleet & Patterson, 2001; Sheridan, Edwards, Marvin & Knoche, 2009; Wood & Bennett, 2000). The constructivist perspective that is fundamental to learning communities recognizes the importance of individual knowledge that is shared in social constructs.

Furthermore, the teachers were engaged in what Speck and Knipe (2001) refer to as concrete experiences that can be used to apply what they learned to their work. The teachers were engaged in looking at student work, reading research articles, and case studies, but the most beneficial activity was the use of video in the professional development. The use of video was an important reflective and learning tool. The teachers viewed video of other teachers using high cognitive demand tasks in the classroom. They viewed video of kindergarten, first and second grades. All the teachers in the study expressed how important they felt the video was to their overall learning. They needed to see a practical example of teachers implementing tasks in the classroom. This is what Sherin (2004) would describe as teachers gaining new knowledge from watching video because they watch the video from the perspective of reflection and analysis. Throughout the study the teachers would discuss the strategies they saw other teachers use and reflect on how they could use those strategies in their classroom.

The first two conclusions listed above indicate a triad of components that resulted in a successful professional development. The triad consists of learning communities, meaningful and relevant video, and accountability. If one component were not in place then it would have greatly affected the success of the professional development. For example, if accountability were not part of the study then the teachers would not have tried to implement the new knowledge they were gaining from the professional development. They would have met the requirements of the study and completed the pre and post conditions, but they would not have used the tasks enough in their classroom to realize the benefits. If meaningful and relevant video were not part of the professional development then the teachers would not have been able to process how to implement tasks in their classroom. They needed a real life example similar to their own classrooms to help them process all the parts of framework. The findings of this study suggest that the teachers would not have been as successful at selecting and implementing high cognitive demand tasks if they did not have this professional development and if the three components above were not an integral part of their learning. This, again, brings to light the research that Speck and Knipe (2001) have done concerning how adults learn.

The necessity of professional development. I believe this is one of the most important outcomes of the study. From the data, it is obvious that before professional development, the teachers did not know how to implement high cognitive demand tasks in their classrooms. After professional development, they improved in all aspects of the implementation. The teachers filled out reflection sheets and they made goals for themselves to improve in how they asked questions, how they supported the students and how they orchestrated the sharing out piece. The teachers were supported by each other and through the professional development. Often, when new policy is enacted at the district level, the piece that is forgotten or is not given adequate attention is the need for professional development. Many times, policy makers announce a new practice that they want implemented and provide information about how it has been researched and that it increases student achievement. Then they tell teachers to “go do,” leaving them with a lack of understanding of how this new practice fits in their classroom and how it fits with everything else they are asked to do. Additionally, the assumption is that because it has been researched then it will work in all classrooms and with all teachers and students. The teachers try to implement the new practice and quickly become frustrated and proclaim that it does not work. Equally tragic, these new practices are implemented without fidelity to how they were researched resulting in different outcomes. The findings from this study indicate that the teachers would not have improved on selecting and implementing high cognitive demand tasks if they did not have professional development.

One cannot ignore the power of volunteerism. These teachers volunteered to be part of this study and to attend professional development. Most of the teachers expressed how they felt the study matched their own personal goal to improve mathematical thinking in their classroom. Two teachers were apprehensive about engaging in this process, but decided they would participate and at the end of the study, they talked about how they were glad they participated because they learned so much. It is difficult to convince teachers to volunteer for professional development and often they are told they must attend. However, the teachers in this study talked about how they were treated as professionals. They had a voice in the professional development, they were provided with snacks and a nice lunch and they were given time to plan the tasks they were going to use in their classroom. Most importantly, the professional development occurred during their contract hours. These things made them feel valued. Frequently, professional development occurs after school when they are already tired or during a workday when they are under pressure to complete tasks that cannot be done when students are in school. Obviously, schools do not have the budget to provide all these things but the point is that teachers want to feel that their time and expertise is valued. I describe my role in the professional development below and then discuss my recommendations for transformative professional development.

My Role in the Professional Development

Innovations are new practices introduced to other people by an individual (Rogers, 2003). According to Rogers' principles of diffusion, the innovation must be brought to the early majority after the innovation has been used and proved effective by an early adopter. In this case, I am the early adopter because Stein, et al. (2009), were the innovators. The teachers in this study are the early majority. The early majority are the people who could complete the diffusion of high cognitive demand mathematical tasks. The early adopter is a leader in the community and the early adopter diffuses the innovation to the early majority. The early majority respects the early adopter because they trust this person's knowledge and evaluation of the innovation.

In this study, the teachers knew me as a leader and trusted my opinions. They knew of my studies, my experiences and successfully worked with me on other endeavors. The teachers did not know about high cognitive demand tasks when we began this study together. The teachers decided to engage in this study because they trusted that I knew the subject well and would not ask them to implement something that would not be worthwhile to their practice. At the conclusion of this study, the teachers become the early adopters and have the potential to diffuse this innovation to other (early majority) teachers. The findings from this study suggest to me that in order for an innovation to be successfully implemented, the teachers must experience the innovation in practice and know a person they trust who had implemented the innovation.

Recommendations for Transformative Professional Development

The teachers in this study found the professional development to be valuable to them as learners. This led me to believe that school based professional development that is facilitated by a trusted leader is essential. This does not mean that district wide professional development is a poor model. However, if the goal is to implement a new teaching practice, then a school-based approach allows for teacher direction and teacher voice. District wide professional development can alienate teachers because it does not take into consideration their needs, concerns or voice. I believe this is why so many teachers leave a district wide professional development thinking, "Those people in the district office have not been in a classroom in so long that they do not know what we really go through each day." Additionally, school based professional development provides a level of support that teachers need to implement new practices that cannot be provided through district wide professional development.

When planning school based professional development, the facilitator needs to understand who he/she is as a facilitator. The facilitator needs to consider what model of professional development works best with his/her personality and goals for the professional development. The facilitator needs to consider who the participants are as learners, and what activities are appropriate for these learners. The facilitator needs to plan a professional development that is relevant to the participants' goal(s), allow for participant voice and choice, and plan activities that the participants can apply to their work. Additionally, the professional development needs to contain time for feedback, reflection and support for the participants to implement the new practice.

The professional development model that I used in this study was a learning community model. This model worked for me as a facilitator and it was appropriate for the teachers who participated. I knew the teachers in this study and I knew they loved to talk and were not shy about expressing their opinions. Additionally, I considered that six of the seven were already team members and had established a level of trust with each other. Then I planned activities that were appropriate to the teachers' learning style. I knew they needed hands-on activities that they could evaluate as useful or not. I knew they loved to watch video of other teachers and therefore I incorporated these activities into the professional development. Planning professional development is a complex task that many facilitators take lightly because they do not consider the above components.

Implications for Future Research

This study was conducted in one elementary school using seven primary (K-2) teachers. Additional research should be conducted in other elementary schools with different primary teachers and a different facilitator. Additionally, the facilitator should not work at the school where the study takes place. Emphasis of this research could include looking more specifically at how primary teachers promote productive discourse in their classrooms. Discourse was an area that the teachers in this study had difficulty promoting in the sense that the students conjecture about each other's work. Additionally, facilitators should look more closely at how teachers assess student work and what they notice about student thinking from that work. Another area to consider for research is the content knowledge a teacher needs in order to select tasks that are high cognitive demand. In this study, it was difficult for the teacher to identify the mathematical thinking a task had the potential to elicit and that could be due to content knowledge.

Another area to consider for future research is the validity of these instruments being used in a primary setting. In order to show a high level of cognitive demand during the instructional episodes, the students need to be generalizing, showing multiple representations and making connections between those representations, and showing mathematical reasoning when working on the tasks. In Kindergarten, in September, it is highly unlikely that students will be doing all those things when solving high cognitive demand tasks. They know only one way to solve a task and it seemed, from this study, to be relying on their own mathematical intuition. For example, a problem that a class of

Kindergartners worked on was how many balloons Mr. Phillips had together if he had eight red balloons and four green balloons. The majority of the students drew eight balloons and four balloons and then counted all the balloons to get the answer of twelve. Some of the students did not even know how to write the number twelve at this point. They did not know another strategy or representation for solving this problem yet. Does that mean they did not engage in solving this task at a high level of cognitive demand? What does a generalization look like in Kindergarten?

Additionally, when assessing discourse in the classroom, perhaps we need to consider the age and maturity of the students when using rubrics to assess their contributions to the task. For students to demonstrate high levels of contribution when sharing they must support their solutions with evidence or reasoning, giving conceptual explanations. This can be done by citing an example or referring to prior classroom experiences. Additionally, students had to connect their contributions to each other and show how ideas/positions shared during the discussion relate to each other. When I discussed this in the professional development, the primary teachers were concerned about how this would look in primary classrooms. Victoria said, "At this age kids are kind of into themselves. They just are interested in sharing what they did. Like, 'I did it this way.' They only think about their thoughts." Lily commented on how students at this age have trouble discerning when their thought adds on to other students thoughts and when it is just really the same thought.

> I think so many of them are still learning at this age, still learning the language and how to explain your *own* (emphasis added) thinking, that it

> takes a lot for them to be able to add on to what someone else is saying. Because even if they hear, like if I hear what Elizabeth says, if it's not exactly my words then I'm going to assume that my thoughts are a completely new thought. Even though they may be related thoughts, the kids don't know how to internalize and then bring on something to contribute more.

This was an area where the teacher had the most difficulty when using tasks in their classroom. They improved on pressing the students for evidence that the solution was correct and they improved on asking probing questions and trying to link student work, but getting the students to respond to each other and make the conjectures the teacher was trying to promote did not happen.

The role of differentiation of tasks in an elementary classroom is another area for future research. Many of the teachers talked about how if they had special education students or English language learners those students were not able to access the task in the same way as other students. They struggled with how to help these students and Phyllis said, "I think I helped her a little more than I should or than I would other children in my class. But it was because I think it is the language that was holding her back not her ability to solve the problem." I think looking at how tasks should be differentiated and how the teachers orchestrate the sharing out of the task when some children have a modified task is a rich area for investigation. The teachers struggled with how to help their students and sometimes felt that these students should just have direct instruction in order to meet their needs as learners. Abby said,

> I think there was a couple that were so far behind that doing more explicit instruction with those students that was really what they needed. I feel like that style [referring to solving tasks] doesn't benefit them because their specific needs as a learner.

Lily felt like not all of her students benefited from using high cognitive demand tasks but thought that since they were exposed to it then perhaps they benefited in some way. The tension between using high cognitive demand tasks in the classroom and meeting the needs of all students is a real issue that needs further research.

Implications for Education Policy

Although not part of the research questions for this study, I asked the teachers some questions about why they felt it was or was not important to use high cognitive demand tasks in the classroom and what they thought might hinder the use of these tasks on a regular basis, if any. I asked them these questions during the interview at the end of this study. The themes that emerged from the data are problem solvers, time, resources and application.

The teachers felt that one of the advantages to using high cognitive demand tasks in the classroom was that students had the opportunity to engage in high-level thinking and problem solving. The tasks help students see that there can be multiple solutions to a problem and it builds the skill of using multiple representations to solve problems. Additionally, it helps the students learn to persevere and become flexible thinkers. Abby said, "It gets them thinking and also on the sharing side it gets them to see different ways to solve the problem. I think that high cognitive demand questions allow them to think of different ways to solve the problem." Other teachers talked about how these tasks help them to see what the students really understand about the math they are learning. Victoria summed up what most of the teachers were saying when she said,

> I feel like it helps kids become better problem solvers. I feel like it helps kids think in more than one way. A lot of times, kids are *very* (emphasis added) fixed in the way they think and they only think one way and if it's not this way it's wrong. I feel like it helps kids see things in different ways to help solve problems.

The teachers all agreed that it was important to use these tasks in the classroom because otherwise the students will not have opportunities to think at higher levels, become better problem solvers, and learn to communicate with each other and to persevere.

However, they expressed that one of the biggest disadvantages to using these tasks was that they are time consuming, not only in planning but in executing them in the classroom. Lily said, "I find having the resources that fit our curriculum is hard to find. Like I spent a lot of time making problems, and then it takes time for the kids to solve the problems and it is sometimes hard to find the time." The teachers really struggled with seeing the value in using the tasks but also letting go of the traditional curriculum. Abby expresses this struggle when she said "I felt like there needs to be more explicit instruction that sometimes we missed because we were working on tasks for so long. I think it is valuable time spent but it is hard to balance everything." Victoria agreed and felt it was hard to let go and fit in a high cognitive task.

> I think too sometimes it does take time and it is hard sometimes to find the time and to be okay with kind of letting go of what we were doing and fitting in, even though it is extremely valuable, but fitting it in.

It is obvious that the teachers struggle with how high cognitive demand tasks fit into the curriculum they are responsible to teach. All of the teachers felt that the one thing that would hinder them in using high cognitive demand tasks regularly was time. They view high cognitive tasks as something else to do instead of an actual part of the curriculum. They did not understand how they could use these tasks to actually teach the curriculum. Many of them felt that they need to teach a skill first and then they could use the tasks to see what the students understood. For example, Abby said, "So, as long as you have explicit instruction on what you need to teach and then you can incorporate a task." Lily agreed, "Like I have found the most beneficial is once you teach place value but then you introduce tasks like these to get them to see and manipulate those subjects in a different way." The good news was all the teachers said they felt high cognitive tasks were beneficial and very valuable to their students' mathematics education. All of them expressed that they will continue to use the tasks as much as they can throughout the school year.

Resources were briefly alluded to in the above paragraph but it warrants more discussion. All of the teachers talked about how there are not enough high cognitive demand tasks available that assess the curriculum they are teaching and that are truly high cognitive. They talked about how they had to spend a great deal of time finding, writing or modifying tasks. Many of them used the internet to locate tasks but most of the time they had to modify the task to either be high cognitive or to better fit what they wanted to assess. All of them felt that teachers might use these tasks more if there were more resources that were readily available. Jill said, “I think resources are crucial. I mean it took me a long time to find sites that have a lot of problems.” Nikki thinks it would be great if the district where she teaches would have these resources readily available and she went on to say, “it’s just finding all the resources. Having a good amount of, yeah just knowing where to get your resources.” Resources are an important district level concern. If a school district is pushing using high cognitive demand tasks in the classroom then the district office needs to provide resources for the teachers. The teachers in this study found resources and did what they had to in order to fulfill their obligation to the study. It is doubtful that teachers would take the same amount of time these teachers did to find their own resources.

The teachers pointed out another advantage to using high cognitive demand tasks and that was so they could assess how their students were applying mathematical knowledge. Additionally, they can see how much their students really understand the mathematics they were taught. Nikki said, “I feel like at first I just wanted to introduce the strategies and then giving the kids the tasks is a great way to apply those strategies.” They felt that providing students opportunities to apply the skills they were learning in math class made the math come alive and that learning math had a purpose in everyday life. Abby expresses this opinion when she said:

> I feel like it is important to give students the opportunity to take what they learn and apply it to different situations. I feel like giving these opportunities to use

> these in the classroom gives them more opportunities to see why math is important and it is not just memorizing like 2 + 2. It is to show them there are real life situations.

So often, teachers teach mathematics to students and students pass tests but when we ask them to apply the math to another situation they cannot demonstrate their knowledge. I have heard people refer to this as doing school. Students can pass tests but when asked to solve a complex task they cannot find a solution. Giving students these tasks is a way to help them learn to apply mathematics and these teachers in this study realized that important point.

These themes point to important considerations for district policy makers. Overall, the teachers from this study recognized the benefits of using high cognitive demand tasks in their classrooms. Therefore, I believe that convincing teachers to use them is not the issue. The issue is lies in the practicality of using these tasks. Elementary teachers typically have one hour to teach math each day. I saw, and the teachers also talked about, how that is not enough time to implement high cognitive demand tasks and to maintain the demand throughout the instructional episode. Consistently, in each classroom, when I observed during the post lesson implementation the teachers gave appropriate time to launch the task, gave appropriate time for the students to work on the task but there was not enough time for the students to share their thinking. If the math block were one and a half hours then there would be enough time. Interestingly, the math blocks are one and a half hours long in the middle and high schools, which is the setting where the majority of the research for high cognitive demand tasks took place. An important consideration for district policy makers is how teachers use these tasks, maintaining cognitive demand, in the time they are allotted for the daily math lesson. A simple response would be to tell the teachers to do the sharing out the next day. However, a couple of teachers from the study did that and they reported that it was not the same as sharing out the day the students worked on the task. They said the students were not as excited or interested the next day and in some cases, they did not remember what they did to solve the problem the day before.

District policy makers should also consider how to make high cognitive demand tasks part of the everyday curriculum. In the district where this study took place, high cognitive demand tasks are used as formative assessments. However, teachers view assessments as a way to know if individual students have learned the curriculum and they do not understand the importance of sharing out solutions if they are using the task for the purpose of assessment. In chapter one, I said that there is concern about what type of mathematics students are learning and if the students are learning in a way that prepares them for the 21st century. One way to ensure that students are being prepared for their future is to provide tasks that give them opportunities to apply the mathematics they learn. Solving complex problems, collaborating, persevering and communicating are pillars of 21st century learning. High cognitive demand task provide that type of learning. My fear is that if teachers are only using these tasks as formative assessments or only occasionally (i.e. when they have time to fit it in) then students are missing important and valuable learning that prepares them for college and/or the work force.

In conclusion, I believe that professional development is another important consideration for district policy makers. In each of the research questions, I asked if professional development impacted the change teachers experienced. I gleefully suggest that it did and would further suggest that professional development take place before teachers begin to select and implement high cognitive demand tasks in their classrooms. However, more important to consider is the type of professional development this study provided.

School based professional development was instrumental in the gains these teachers made. At the school where the study took place, there was an ongoing focus on student thinking and transfer. This provided the perfect inception for this study because the teachers were already primed for learning more about how to engage students in mathematical thinking. If this study took place at a different school where student thinking and transfer was not a focus, then the results could be different simply because the professional development being offered was not in alignment with the school or teachers goals. The first consideration when planning professional development is the relevance to what is happening in the classroom.

Another way this professional development provided opportunity for teacher growth was the learning communities design. This design gave the teacher time to talk, grapple with new knowledge, feel less isolated and engage in a shared community of learners. The teachers felt like they learned from me, the facilitator, but also from each other. When professional development is designed like a class where there is a hierarchy of the knowledgeable person over the less knowledgeable, teachers do not always feel like what you are trying to teach them translates to their own classroom. If they feel like it does translate then they do not always feel confident that they can implement the new knowledge. Talking with people they trust and work with every day helped the teachers in this study internalize the ideas and feel confident in their ability.

Common Core State Standards and No Child Left Behind. The findings from this study are not just limited to selecting and implementing high cognitive demand tasks in the classroom. These findings can expand our knowledge about the Common Core State Standards (National Governors Association, 2010) and the No Child Left Behind Act of 2001. The implementation of the Common Core Standards has been a rocky, uphill battle. However, as states continue to struggle with its implementation, they should consider Rogers' (2003) factors for adoption. A trusted and knowledgeable early adopter should provide the professional development needed to diffuse this innovation. Additionally, the teachers need to see or experience this innovation as beneficial to their teaching practice and to their students. They must experience the results of this new practice.

High cognitive demand mathematical tasks are in alignment with the mathematical practices outlined in the Common Core. The assessments from the Common Core, that are being tested, are application-based questions, which mirror high cognitive demand tasks. As teachers learn to select and implement these tasks, they are preparing their students for the Common Core assessments and following the mathematical practices of the curriculum. The value of using these tasks in the classroom is directly transferable to a classroom where Common Core is practiced.

No Child Left Behind, in my view, points to two things. The first is that all subgroups are now "visible" to everyone. We cannot hide the fact that minorities are not passing and are receiving an inequitable mathematics education. The second is that the focus is on kids passing tests and not on the deeper mathematical understandings that are so important for children who are growing up in the 21st century. I believe that it is the intersection of kids passing tests and teachers using tasks in their classroom that promote mathematical thinking, that causes tension to apply higher level thinking in the classroom. I believe this is why the teachers from this study feel that high cognitive demand tasks are separate from their everyday responsibilities to the curriculum. As a country, we are still in need of a paradigm shift to focus on mathematical meaning equal to the amount of focus we place on kids passing tests.

Finally, at the end of this journey, through this dissertation, I recognized that teacher learning and development is a complex process. Teachers want to improve their practice, they just do not know how it fits into the complexities of teaching in a world where the ultimate goal is students passing tests. I also realized that teacher learning and development is often slow and should be a career long venture, and I am reminded of what Stigler and Thompson (2009) think, gradual movement in the desired direction is an important accomplishment. Phyllis expressed this best when she told me how much participating in this study meant to her;

> I've grown as a teacher from this and I've taken away something from it. And this kind of ties to this after school special I went to about number talks. It's kind of got me thinking about how I'm going about instructing kids, that it is not about

algorithms and that, and I'm thinking that is the wrong way to do it. So, I'm kind of veering off of that track, trying to look at this and then think about a different way to get kids to understand what they are doing not just, I move this here and move this here, leave that out, cross this off kind of stuff, you know.

APPENDIX A: IRB APPROVAL LETTER

GEORGE MASON UNIVERSITY | Office of Research Integrity and Assurance

Research Hall, 4400 Univeristy Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-5445; Fax: 703-993-9590

DATE:	June 3, 2014
TO:	Margret Hjalmarson, PhD
FROM:	George Mason University IRB
Project Title:	[591815-1] High Cognitive Mathematical Tasks
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	June 3, 2014
EXPIRATION DATE:	June 2, 2015
REVIEW TYPE:	Expedited Review
REVIEW TYPE:	Expedited review category #7

Thank you for your submission of New Project materials for this project. The George Mason University IRB has APPROVED your submission. This submission has received Expedited Review based on applicable federal regulations.

Please remember that all research must be conducted as described in the submitted materials.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by the IRB prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to the Office of Research Integrity & Assurance (ORIA). Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed (if applicable).

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to the ORIA.

The anniversary date of this study is June 2, 2015. This project requires continuing review by this committee on an annual basis. You may not collect date beyond this date without prior IRB approval. A continuing review form must be completed and submitted to the ORIA at least 30 days prior to the anniversary date or upon completion of this project. Prior to the anniversary date, the ORIA will send you a reminder regarding continuing review procedures.

Please note that all research records must be retained for a minimum of three years, or as described in your submission, after the completion of the project.

If you have any questions, please contact Karen Motsinger at 703-993-4208 or kmotsing@gmu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within George Mason University IRB's records.

APPENDIX B: RECRUITMENT EMAIL

Hello Teachers,

As you know, I am getting my Ph.D. from GMU. I am ready to conduct a study for my dissertation and I'd like to do this study here at school. If you think you'd be interested in participating in my study about high-cognitive demand mathematical tasks, please attend a brief information session in the conference room at 3:15 PM on 6/19.

Thanks,

Dori Hargrove

APPENDIX C: TEACHER CONSENT FORM

High Cognitive Demand Mathematical Tasks

INFORMED CONSENT FORM

RESEARCH PROCEDURES
This research is being conducted to discover how teachers' understanding of high cognitive demand tasks and the implementation of these tasks change through professional development. If you agree to participate, you will be asked to attend three professional development sessions that are video recorded, complete a pre and post sorting activity that is audio recorded and complete reflections of what you are learning from the professional development. Additionally, you will provide a pre and post collection of mathematical tasks that you use in your classroom and provide student work from mathematical tasks that you use in your classroom. You will be required to black out or remove the student name from the work before submitting it to the researcher. You agree to a pre and post videotaped observation in your classroom as you implement mathematical tasks. Note that the video recording of the implementation will focus on you (the teacher) and not the students in your classroom. You also agree to an audio-recorded interview detailing your view of using mathematical tasks in your classroom on a regular basis. You agree to one other video recording of classroom implementation of a task that will be used as a learning tool at the third professional development session. This video will not be used to collect data. You also agree to fill out a demographics form letting me know of your years teaching experience, level of education, any endorsements to your teaching license, and what grade levels you have taught during your career. You may opt out of being video and/or audio taped.

RISKS
There are no foreseeable risks for participating in this research.

BENEFITS
There are no benefits to you as a participant other than to further research in mathematics education in the area of teacher change and how performance tasks can be used as formative and summative assessments.

CONFIDENTIALITY
The data in this study will be confidential. As you are observed, videotaped, and audio taped throughout this study the researcher will know your identity. The audio and video tape will be stored in a locked file until the data analysis is completed and then it will be erased. Your name will not be used in the final report; rather a pseudonym will be used. Additionally, neither the school nor the school district will be identified in the final report.

PARTICIPATION
Your participation is voluntary, and you may withdraw from the study at any time and for any reason. You may opt out of being video and/or audio taped. If you decide not to participate or if

you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party. Your participation is not expected or required as an employee of FCPS.

CONTACT
This research is being conducted by Dori Hargrove at George Mason University. Dori may be reached at 703-371-4764 for questions or to report a research-related problem. You may also contact the principle investigator, Dr. Margret Hjalmarson at 703-993-4818. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research. Additionally, Fairfax County Public Schools has reviewed and approved this research.

CONSENT

I have read this form and agree to participate in this study. Please check one of the boxes below.

☐ I agree to be video and audio taped

☐ I agree to be audio taped only

☐ I agree to be videotaped only

☐ I agree to participate but wish to opt out of being video and audio taped

____
Name

____
Date of Signature

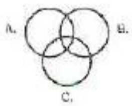
APPENDIX D: HIGH COGNITIVE DEMAND TASKS

Task Number	Task
1	Measure the leaf in as many ways as you can. Tell how you made each measurement and what you discovered.  Retrieved from http://www.rda.aps.edu/mathtaskbank/pdfs/tasks/k-2/tk2WonderLeaves.pdf
2	Marilyn went to the candy store. She saw as sign that said when you buy your first piece of candy it cost 5 cents, but each piece of candy after that would cost only 3 cents. Marilyn had 11 cents to spend. How many pieces of candy did Marilyn have after giving the clerk her 11 cents?
3	Daniel put 5 blocks in a bag. 4 were red and 1 was yellow. Tom reached in the bag and pulled out one block? What color block was he most likely to pull out of the bag? Use math to show your thinking.
4	Sally baked 12 cookies to share evenly with her friends. Each friend and Sally got 2 cookies. How many friends did Sally share her cookies with?
5	A farmer planted 9 seeds of corn. What are some of the different ways he could put them in even rows?
6	Mark decided to make his mom a new necklace. First, he put a blue bead on a string. Next, he put a red bead on the string. If he continues the pattern in the same way, what color are the next two beads?
7	4 children. 2 cans of playdough. How can they share the playdough equally? Retrieved from http://www.rda.aps.edu/mathtaskbank/pdfs/tasks/k-2/tkletsp.pdf

8 Mrs. Beatle was planting a flower garden. In the first row she planted 5 daises. In the second row she planted 10 roses. If the pattern continues in the same way, how many flowers did she plant in the next row. What is the rule? Explain your thinking in pictures, numbers, or words.

9 Mark found a dime in one pocket and spent it on a lollipop that cost 4 cents. How much money does Mark have now?

10 The lizards have a choice of what ring to enter. Four lizards are in ring A. Three lizards are in ring B. Four lizards are in ring C. Three lizards are in ring A and B only. One lizard is in rings B and C only. How many lizards are in the rings? Use cubes to help you solve.



11 Fill in the missing numbers below:

26, 27, _____, 29, ______

12 Name the number that comes before seventy. What number comes between 12 and 14? Name the number that comes after 39.

13 Five yellow cats and three brown cats are on the porch. Write a number sentence to show how many cats there are on the porch. Explain your thinking.

14 How could you fold a square piece of paper to make: 4 squares? 2 rectangles? 4 rectangles? 2 triangles? 4 triangles? Give the child a square piece of paper to solve this problem. Explain how you solved using pictures, numbers, or words.

15 Mary has two red balloons, three blue balloons, and 1 green balloon. Ian has seven yellow balloons. Who has more balloons? Draw a picture and explain your thinking.

16 Mr. Kraft wants to move a bookcase to another place in the classroom, but he wants to be sure that it will fit in the new space before he moves it. How can he do that? Develop a measuring plan and explain it to the class.

17 What comes next? Describe the pattern.

1, 2, 1, 3, 1, 4, 1, _____, _______, _______ 18 How many ways can you make 9? Draw pictures and explain your thinking.

19 Solve the problem below:

$3 + 6 = 6 + \square$

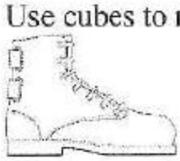
20 Place the months of the year in order.

June, December, July, January, April, August, October, March, November, February, May, September.

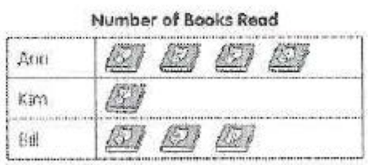
21 Write a story problem to match this number sentence.

$10 - 3 = 7$

22 Use cubes to measure the boot. How long is the boot? How do you know?



23 The graph shows the number of books read by 3 children in a week.



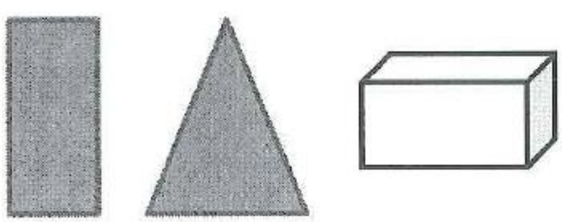
1. __________ read the most number of books.

2. __________ read the fewest number of books

3. The three children read ________ books in all.

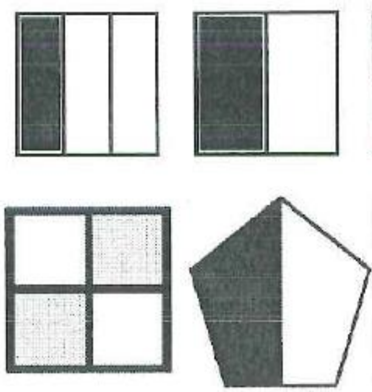
Retrieved from http://images.pcmac.org/SiSFiles/Schools/AL/MobileCounty/CouncilTraditional/Uploads/Forms/Chapter%2011%20Extra%20Practice.pdf

24 Which two figures are most alike? Explain your thinking.

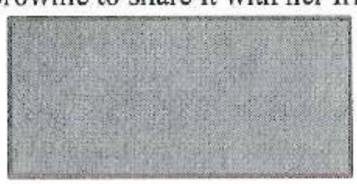


25 Brandon's dad bought a bag of 12 peanuts to feed the elephants. When Brandon and his dad arrived at the zoo they saw 7 elephants and then 4 more arrived. Do they have enough peanuts to feed the elephants? Show how you found the answer using words, numbers, or pictures.

26 Circle all the figures that show one half. Explain how you know.



27 Sue wanted to share her brownie with two of her friends. Show how Sue would cut her brownie to share it with her friends.



28 Write the number sentence that is missing from the fact family. How do you know?

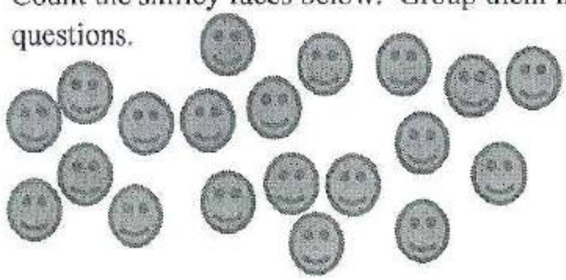
$3 + 5 = 8$
$5 + 3 = 8$
$8 - 3 = 5$

____

29 Put an S in all the squares. Put a C in all the circles. Put a T in all the triangles. Put an R in all the rectangles.

30 Write a fraction for each figure below.

31 Count the smiley faces below. Group them in 10's. Then answer the questions.



How many tens_____?

How many altogether _________?

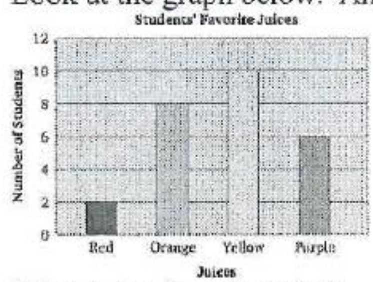
32 Kelly the Kangaroo only hops by 10's. If she is on the number 20, how many hops will it take her to land on number 100? Explain your thinking below.

33 **Solve. SHOW YOUR THINKING!**

Laura counted 36 stickers. Andy counted more. How many did Andy count?

34 What is the best title for this group? Explain why?

35 Look at the graph below. Answer the questions



What is the favorite juice?

What is the least favorite juice?

Retrieved graph from https://www.google.com/search?site=&tbm=isch&source=hp&biw=1366&bih=622&q=bar+graphs+for+kids

36 Count the coins below. Tell how much money?

____

____

37 Use manipulatives to solve the problem below. Explain your thinking using pictures, numbers and/or word.

There were 26 girls and 38 boys on the playground. How many children were on the playground at recess?

38 Six children ordered blueberry pancakes at a restaurant. The waiter brought 8 pancakes to the table. If the children share the pancakes evenly, how much can each child have? Use pictures and/or words to explain your thinking.

39 Amna and Hari have 7 cookies. If they share them equally, how many cookies would each child have? Use pictures and/or words to explain your thinking.

40 Alex had 15 toy cars. He gave some away. Now, Alex has 8 toy cars. How many did he give away? Explain your thinking using pictures, numbers and/or words.

APPENDIX E: PRE AND POST OBSERVATION INTERVIEW PROTOCOL

Pre:

1. What is your objective for today's lesson?
2. Describe the goals that you wish to accomplish today?
3. What are your intended outcomes?
4. How will the students complete the task (i.e. individually, small group)?
5. What is the academic relationship between this lesson with past or future lessons?

Post:

1. What part of the lesson do you think was most successful?
2. What part of the lesson do you think was unsuccessful?
3. Do you think that you maintained the cognitive demand of the task throughout the instructional episode? Explain.
4. How would you describe the student contribution to the lesson?
5. Did you discover anything new about your teaching?

APPENDIX F: INTERVIEW PROTOCOL

I am interested in finding out about your views of using high-cognitive demand tasks in the classroom. Your answers to the questions will provide insights for me to understand what you think about how high-cognitive mathematical tasks can be implemented in the classroom successfully and what hinders the successful implementation of tasks. Please be mindful that your answers will be completely confidential. Thanks in advance for sharing your thoughts about high-cognitive demand tasks.

Why use high-cognitive tasks in the classroom.

1- What are the advantages of using high-cognitive demand tasks in the classroom?

2- What are the disadvantages of using high-cognitive demand tasks in the classroom?

3- What type of mathematical understandings do you think high-cognitive demand tasks provide for students?

4- Do you feel high-cognitive demand mathematical tasks are needed to provide this type of mathematical understanding or can that same level of understanding be achieved in other ways? What ways?

5- How would you describe a successfully implemented high-cognitive demand task?

Professional Development.

6- How did the professional development meet your needs as a learner?

7- How did the professional development fail to meet your needs as a learner?

8- What part or parts of the professional development did you find most useful to you as a learner?

9- When you compare this professional development to others you have experienced, what makes this professional development experience more/less beneficial to you as a learner?

Policy Issues

10- How do you see successful implementation of high-cognitive demand tasks playing out in your classroom over time?

11- What do you feel is necessary to the successful implementation high-cognitive demand tasks in the classroom?

12- Did you think all students in your classroom benefitted from using high-cognitive demand tasks in the classroom? Is so, how? If not, why?

13- How often do you think you should use high-cognitive demand tasks in the classroom?

How often will you use high-cognitive demand tasks in the classroom?

What keeps you from using high-cognitive demand tasks daily?

Is there anything you would like to say that we have not already discussed?

APPENDIX G: PROFESSIONAL DEVELOPMENT AGENDA

Day	Activity	Purpose
Day 1 – Part 1+	Teachers filled out demographic sheet	To gather background information on the teachers
	Teachers completed 2 tasks Martha's Carpet Task Fencing Task	For teachers to differentiate between a low and high cognitive demand task
	What is a High Cognitive Demand Task?	Define – so teachers know how to identify tasks
	What are mathematical thinking, reasoning and connections?	To help teachers identify these components in a task.
	Look at research from Stein, et al. on high cognitive demand. Passed out levels of cognitive demand chart from Stein, et al.	To give teachers background on the research and to show them the levels of cognitive demand so they can identify task.
	Sorted Tasks and discussed the sorts	To have the teachers apply their knowledge of high cognitive demand tasks.
	Case Study – Read and discussed – *The Case of Ron Castleman*	Teachers could read about an actual implementation of a high cognitive task. Discuss how scaffolding is an important part of maintaining cognitive demand.
Day 1 Part 2+	Sorted Tasks and discussed the sorts	To have teachers apply their knowledge of high cognitive demand task
	Read the article "Thinking	To give teachers a tool for planning

	Through a Lesson Protocol" and discussed components of implementing tasks in the classroom	a task implementation and an understanding of what maintaining cognitive demand when implementing means.
	Case Study – Read and discuss – *Compare and Connect Strategies*	Teachers could read about an actual implementation of a high cognitive task.
	Housekeeping items	Sign up for lesson observation. Discuss how to collect tasks and student work samples.
	Planning Time	Teachers had planning time during the professional development to locate tasks and plan lessons to implement those tasks.
	Completed reflection sheet	To gather information on what the teachers were learning and their comfort level with high cognitive demand tasks
Day 2	In depth discussion on how to implement high cognitive demand tasks in the classroom. Showed eight videos and discussed.	For teachers to see how other teachers implement tasks and to relate what those teachers did to their own classroom.
	Student work samples	Look at how to assess student work from high cognitive tasks.
	Show video of implementation of high cognitive tasks in a 1st grade classroom (not in this study) from the school where the study takes place. Look at student work samples from this lesson.	For teachers to view all the components of a task implementation from a familiar population. Practice assessing the student work samples.
	Case Study – *What is the best way to count?*	Teachers could read about an actual implementation of a high cognitive task.

	Task Sort - Discuss	To have teachers apply their knowledge of high cognitive demand task.
	Housekeeping items	Teachers signed up for the video of them implementing that was not used as data but was used during the 3rd PD.
	Planning Time	Teachers had planning time during the professional development to locate tasks and plan lessons to implement those tasks.
	Complete Reflection	To gather information on what the teachers were learning and their comfort level with high cognitive demand tasks.
Day 3	Open discussion on what teachers are learning and self-assessment	To give the teachers time to ask questions, discuss successes and short-comings with colleagues. To give the teacher time to reflect on where they were at the beginning of this study to where they are now.
	Discuss the viewing guide to watch their own video	To familiarize the teachers with how to use the guide and to focus on the items to help them see area to work on and areas of success.
	Individual teacher views her own video and then pairs up with another teacher and view that teacher's video. They discuss what the saw.	Teachers see their teaching from a different perspective and identify areas they want to improve. Watch a video of another teacher in the study to see strategies that teacher uses and to encourage and constructively critique each other.
	Whole group discussion of the videos.	To give teachers time to reflect on what they observed and discuss strategies, successes and areas for improvement with each other.

Case Study – *Building on Student Ideas*	Teachers could read about an implementation of a high cognitive task and how the teacher linked student work.
Housekeeping items	Teachers signed up for the post lesson observation, task sort interview and final interview.
Planning time	Teachers had planning time during the professional development to locate tasks and plan lessons to implement those tasks.
Complete reflection	To gather information on what the teachers were learning and their comfort level with high cognitive demand tasks.

+ The first PD was divided into 2 after school sessions.

APPENDIX H: COVER SHEET FOR TASK COLLECTION

Task Collection Log Sheet

Week of ____________ **Teacher ________________**

Task #	Purpose of the task in the lesson	Time Spent on the task	Expectations of the task

APPENDIX I: PROFESSIONAL DEVELOPMENT REFLECTIONS

Reflection after 1st Professional Development Session

1. How has your thinking about high-cognitive demand tasks changed after this professional development?
2. What questions or concerns do you have about using high-cognitive demand tasks in your classroom?

Reflection after 2nd Professional Development Session

1. What did you learn from watching the videos of teachers using high cognitive demand tasks in their classroom?
2. Reflect back to when you used the high-cognitive demand task in your classroom after the 1st professional development session. Do you think you maintained or lowered the cognitive demand of the task when you used it in your classroom? Why?
3. What do you plan to do differently when you use the task from today's professional development in your classroom?

Reflection after 3rd Professional Development Session

1. What did you learn from watching the video of yourself using a high cognitive demand task in your classroom?

2. Do you feel you improved from the first time you used a high cognitive demand task in your classroom? How?
3. What do you plan to do differently when you use the task from today's professional development in your classroom?

APPENDIX J: INDIVIDUAL TEACHER TASK SORT RECORD-PRE AND POST

Table J1

Jill - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 8, 14, 18, 21, 27, 34, 37	31
	Low Cognitive	6, 11, 17, 22, 23, 28, 30	26
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 14, 18, 21, 27, 34	6
	Low Cognitive	11, 17, 23, 30, 31	37
	Refused to Classify		8, 22, 26, 28

Victoria - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 8, 14, 18, 27	17
	Low Cognitive	6, 11, 22, 23, 28, 30, 31	21, 26, 34, 37
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 5, 8, 14, 18, 26, 34, 37	28
	Low Cognitive	6, 11, 17, 22, 23, 30, 31	2, 4, 21, 27

Phyllis - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 8, 14, 18,	30, 31
	Low Cognitive	6, 11, 17, 22, 23, 28	21, 26, 27, 34, 37
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 14, 18	31
	Low Cognitive	6, 11, 17, 22, 23, 26, 27, 28, 30	8, 21, 34, 37

Lily - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 8, 14, 18, 34, 37	17, 28
	Low Cognitive	6, 11, 22, 23, 30, 31	21, 26, 27
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 5, 8, 14, 18, 21, 34, 37	
	Low Cognitive	6, 11, 17, 31, 22, 23, 28, 30	4, 26, 27

Nikki - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 8, 14, 26, 37	28
	Low Cognitive	6, 11, 17, 22, 23, 30, 31	4, 5, 18, 34, 21, 27
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 8, 14, 18, 21, 26, 34, 37	22, 28
	Low Cognitive	6, 11, 17, 23, 30, 31	4, 5, 27

Abby - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 5, 8, 14, 18, 26, 34, 37	22, 28
	Low Cognitive	6, 11, 17, 23, 30, 31	2, 4, 21, 27
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 5, 8, 14, 18, 21, 26, 27, 34, 37	17, 22, 28
	Low Cognitive	6, 11, 23, 30, 31	2, 4

Hilary - Sorts			
Pre-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 8, 14, 34	
	Low Cognitive	6, 11, 17, 22, 23, 28, 30, 31	18, 21, 26, 27, 37
Post-Sort	Classification	Correctly Placed	Incorrectly Placed
	High Cognitive	1, 2, 4, 5, 14, 18, 21, 34	
	Low Cognitive	6, 11, 17, 22, 23, 28, 30, 31	8, 26, 27, 37

APPENDIX K: DATA COLLECTION RECORD AND MISSING DATA TABLE

Table K2

Data Collection Record - Completed

Data	**Jill**	**Victoria**	**Phyllis**	**Lily**	**Nikki**	**Abby**	**Hilary**
Pre Task Sort Interview	✓	✓	✓	✓	✓	✓	✓
Post Task Sort Interview	✓	✓	✓	✓	✓	✓	✓
Pre Lesson Observation	✓	✓	✓	✓	✓	✓	✓
Post Lesson Observation	✓	✓	✓	✓	✓	✓	✓
Pre Task Collection	+ ✓	++ ✓	✓	✓	✓	✓	✓
Post Task Collection	✓	✓	✓	✓	✓	✓	✓
PD Reflection One	✓	✓	✓	✓	✓	✓	✓
PD Reflection Two	✓	✓	✓	✓	✓	✓	✓
PD Reflection Three	✓	✓	✓	✓	✓	✓	✓
Final Interview	✓	✓	✓	✓	✓	✓	✓

NOTE: ✓ = Data collected. + = teacher only turned in 3 tasks with 6 student samples. ++ = teacher turned in 4 tasks but one task only had 4 students samples.

APPENDIX L: TEACHER VIDEO – VIEWING GUIDE

1. Find evidence of incidents where you provided opportunities for students to engage with the task at a high level.
    - Provided sufficient time for the students to work on the task
    - Held students accountable for high level contribution to the task
    - Pressed the students for explanation, meaning, and evidence
    - Encouraged students to make conceptual connections
    - Supported the students by scaffolding while maintaining the cognitive demand of the task.
    - Provided students access to resources necessary to solve the task
    - Other areas not mentioned above
2. Find evidence of an environment where students have opportunities to engage with the task at a high level.
    - Classroom management did not interfere with students' ability to engage with the task at a high level.
    - Students had sufficient time to grapple with the task
    - Students felt comfortable sharing their thinking with the class or small group
    - Students had appropriate background knowledge to engage with the task

- Other areas not mentioned above

3. Find evidence where the whole group sharing provided opportunities for the students to engage with the task at high levels.
   - Students used and shared multiple strategies
   - Students made connections between the strategies
   - Teacher asked probing questions
   - Teacher linked student thinking to another student(s) thinking
   - Other areas not mentioned above

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