

From the Common Core to the Classroom:  
A Professional Development Efficacy Study for the  
Common Core State Standards for Mathematics

by

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## ABSTRACT

In this mixed-methods study, I examined the relationship between professional development based on the Common Core State Standards for Mathematics and teacher knowledge, classroom practice, and student learning. Participants were randomly assigned to experimental and control groups. The 50-hour professional development treatment was administered to the treatment group during one semester, and then a follow-up replication treatment was administered to the control group during the subsequent semester. Results revealed significant differences in teacher knowledge as a result of the treatment using two instruments. The *Learning Mathematics for Teaching* scales were used to detect changes in mathematical knowledge for teaching, and an online sorting task was used to detect changes in teachers' knowledge of their standards. Results also indicated differences in classroom practice between pairs of matched teachers selected to participate in classroom observations and interviews. No statistical difference was detected between the groups' student assessment scores using the district's benchmark assessment system.

This efficacy study contributes to the literature in two ways. First, it provides an evidence base for a professional development model designed to promote effective implementation of the Common Core State Standards for Mathematics. Second, it addresses ways to impact and measure teachers' knowledge of curriculum in addition to their mathematical content knowledge. The treatment was designed to focus on knowledge of curriculum, but it also successfully impacted teachers' specialized content knowledge, knowledge of content and students, and knowledge of content and teaching.

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# CHAPTER 1

## INTRODUCTION

### **Overview**

For the past century, psychologists, educators, and mathematicians have cited repeatedly that schools need to stop simply showing students *how* to do mathematics and dive deeper into helping them understand the *whys* of mathematics. In 1922, in *The Psychology of Arithmetic*, Edward Thorndike asserted that educators should ensure that students learn to solve real-life problems and be able to justify their thinking as opposed to blindly applying procedures without any real sense-making (Thorndike, 1922). Various mathematics reform efforts in the past several decades have promoted the notion that developing deep mathematical understanding within our students must take precedence over isolated procedural arithmetic for the United States to be internationally competitive (Confrey, 2007; National Council of Teachers of Mathematics [NCTM], 1989, 2000; Schmidt & Houang, 2012). However, changing the way in which students interact with and apply mathematics requires that teachers shift their classroom practices in significant and profound ways (Cobb & Jackson, 2011; Porter, McMaken, Hwang, & Yang, 2011; Schmidt & Houang, 2012).

### **Mathematics Policy: The Common Core Standards**

The Common Core State Standards for Mathematics (CCSSM) provides a response for students to learn to think mathematically and use mathematics as a tool for solving real-life problems (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). By prescribing a focused, coherent, and rigorous

set of content standards for each grade level, accompanied by a set of standards for mathematical practice (SMP) that promote deep thinking and problem solving, the CCSSM offers promise that the next generation will learn to appreciate mathematics as a tool for everyday life rather than a set of procedures that must be mastered for their school work (Cobb & Jackson, 2011; Porter et al., 2011). However, regardless of CCSSM's promise, in its current form, it is nothing more than a document awaiting implementation—educational policy. Only through the skilled enactment of knowledgeable classroom teachers will the CCSSM take on meaning and utility in the minds of our youngest citizens (Cobb & Jackson, 2011).

The road to creating a skilled, knowledgeable mathematics teaching force is certainly not clear at this point (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). As was true in past mathematics reform efforts, policy, written curricula, research studies, and other support materials have proven to be helpful, but insufficient, in positively impacting mathematics teaching at the classroom level (Confrey, 2007; Jardine, Clifford, & Friesen, 2008; Kaufman & Stein, 2010; Lappan, 1997). The transformation of mathematics teaching requires the transformation of the teachers themselves, as well as shifts in classroom practice (Ball, Thames, & Phelps, 2008; Borko, 2004; Cobb & Jackson, 2011).

For the common core to make its way into the classroom, teachers must possess an intimate knowledge of the mathematics content and the pedagogical expertise needed to operationalize the CCSSM (Ball et al., 2008; Borko, 2004; Cobb & Jackson, 2011). Because so many elementary teachers lack such mathematics content and pedagogical expertise across the United States, professional learning opportunities are crucial for a

successful implementation of the CCSSM. Well-written curriculum policy, the CCSSM in this case, only gains utility when implementation occurs at the classroom level (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012).

### **Professional Development**

Professional development plays a central role in increasing teachers' mathematical knowledge for teaching (MKT). To transform teachers' understanding of mathematics and how to teach it, focused learning experiences for teachers plays a central role. Learning, for students and for adults, is a process whereby the learner actively constructs knowledge by modifying or revising existing ideas (Borko, 2004; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Shulman, 1986). Learning is activated through experiences and reflection on those experiences (Ferrini-Mundy, Burrill, & Schmidt, 2007; Loucks-Horsley et al., 2010). Therefore, quality professional development design intended to impact teacher learning should include activity-based experiences, interactions with people and resources, and reflection opportunities that connect participants' current knowledge to the new ideas developed through the learning goals (Desimone, 2009; Desimone, Porter, Birman, Garet, & Yoon, 2002; Loucks-Horsley et al., 2010).

Furthermore, quality professional development is designed to draw out the ideas learners hold and make useful connections between participants' existing ideas and the ideas tied to the learning goals. Because learning is situated within social contexts in which learners interact with one another, the facilitator or teacher, and the content (Borko, 2004), quality professional development design should facilitate collective participation and interaction between participants.

The primary features found throughout the literature that comprise effective professional development include

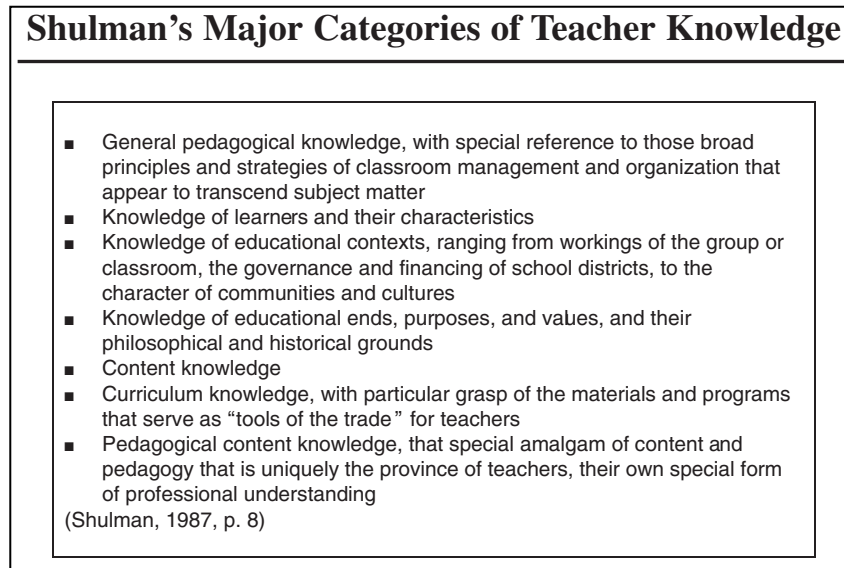
- a focus on content, in this case, mathematics;
- activity-based learning experiences for participants, with opportunity to reflect on those experiences;
- coherence between the professional development goals and participant goals, as well as between the professional development and other competing initiatives (e.g., ELL training, textbook adoptions, new evaluation systems, etc.);
- duration over a period of time, typically 30–100 hours; and
- collective participation among peers (Borko, 2004; Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Desimone, 2009; Desimone et al., 2002; Loucks-Horsley et al., 2010).

The professional development treatment designed for this study took into account each of these components, carefully weaving them into a focused learning experience focused on the CCSSM.

### **Mathematical Knowledge for Teaching**

Most experts would agree that teacher content knowledge matters—that understanding both content and pedagogy is critical to teacher success. Teacher effectiveness requires knowledge far beyond simply *what* to teach, reaching into realms of both general and specific pedagogical knowledge, knowledge of learners, knowledge of educational contexts, knowledge of educational ends, content knowledge, curriculum knowledge, and pedagogical content knowledge (Ball et al., 2008; Shulman, 1987).

Figure 1 includes the seven categories of teacher knowledge outlined by Shulman and colleagues (Ball et al., 2008). These different types of knowledge contribute to teacher effectiveness.



*Figure 1.* Shulman's major categories of teacher knowledge. From "Content knowledge for teaching: What makes it special?" by D. L. Ball, M. H. Thames, and G. Phelps, 2008, *Journal of Teacher Education*, 59, p. 391.

Noting that teacher knowledge falls into several domains, using a more focused lens to concentrate on one subject area, mathematics in this case, provides a focal point through which Shulman's categories reveal themselves with more specificity (Ball et al., 2008). Teacher understanding of both mathematics content and mathematics-specific pedagogy plays a critical role in both classroom instruction and professional development (Ball et al., 2008).

MKT may be grouped into two categories: subject matter knowledge and pedagogical content knowledge (Ball et al., 2008). Ball's group subdivided these two areas into six domains (see Figure 2). A more detailed description of these domains appears in Chapter 2. Note that in this model, as well as in the Schulman's categories of

teacher knowledge mentioned above, one should resist the notion to view these categories, or domains, as entities that exist in isolation from one another. In fact, there may be a tremendous amount of overlap when each of these is observed in a classroom setting (Ball et al., 2008).

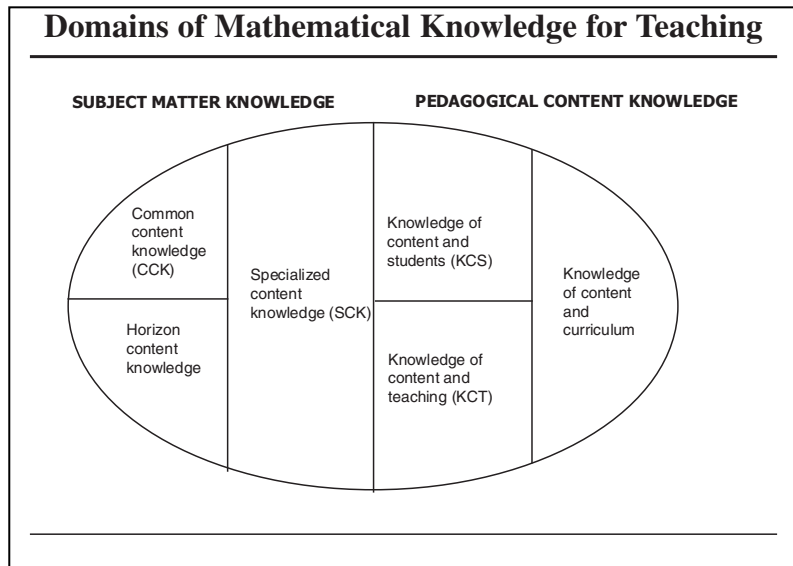


Figure 2. Ball’s domains of mathematical knowledge for teaching. From “Content knowledge for teaching: What makes it special?” by D. L. Ball, M. H. Thames, and G. Phelps, 2008, *Journal of Teacher Education*, 59, p. 403.

Both the professional development treatment design and study design for this dissertation reflected these six domains to offer a balanced look at the different types of knowledge teachers need for successful classroom implementation.

### **Classroom Implementation and Student Learning**

A primary goal of quality professional development centers on impacting teacher knowledge that translates into changes in classroom practice and student learning (Darling-Hammond et al., 2009; Loucks-Horsley et al., 2010). The professional development literature often neglects to focus on such changes, and yet, without



monitoring classroom practice and student learning, the success of teacher learning opportunities remains uncertain (Darling-Hammond et al., 2009; Guskey, 2000; Loucks-Horsley et al. 2010; Spillane, 2000, 2004).

Although the professional development treatment design for this study included opportunities for the participants to engage in mathematics-focused conversations, to interact with mathematics tasks, to anticipate student responses, to collect and analyze student work, and a plethora of other teacher learning opportunities, the impact on classroom practice and student learning was secondary. The study design included classroom observations, teacher interviews, and student assessment analyses to detect such impact.

### **Theory of Change**

Upon review of the literature on mathematics standards, professional development, teacher knowledge, and the impact of professional development on teaching and learning, a theory of change was constructed. This theory of change hypothesized the relationships between professional development for standards-based mathematics and teacher knowledge, classroom practice, and student learning. Traces of the theoretical framework for professional development (Desimone, 2009), guidelines for professional development evaluation (Guskey, 2000), and components for professional development design (Loucks-Horsley et al., 2010) discussed in Chapter 2 appear throughout. This theory of change, in conjunction with the literature review in the Chapter 2, forms the foundation for both the study design and the professional development treatment design in this dissertation. Though this framework is more

comprehensive than the study at hand, it incorporates all of the critical elements of both the research design and the treatment elements.

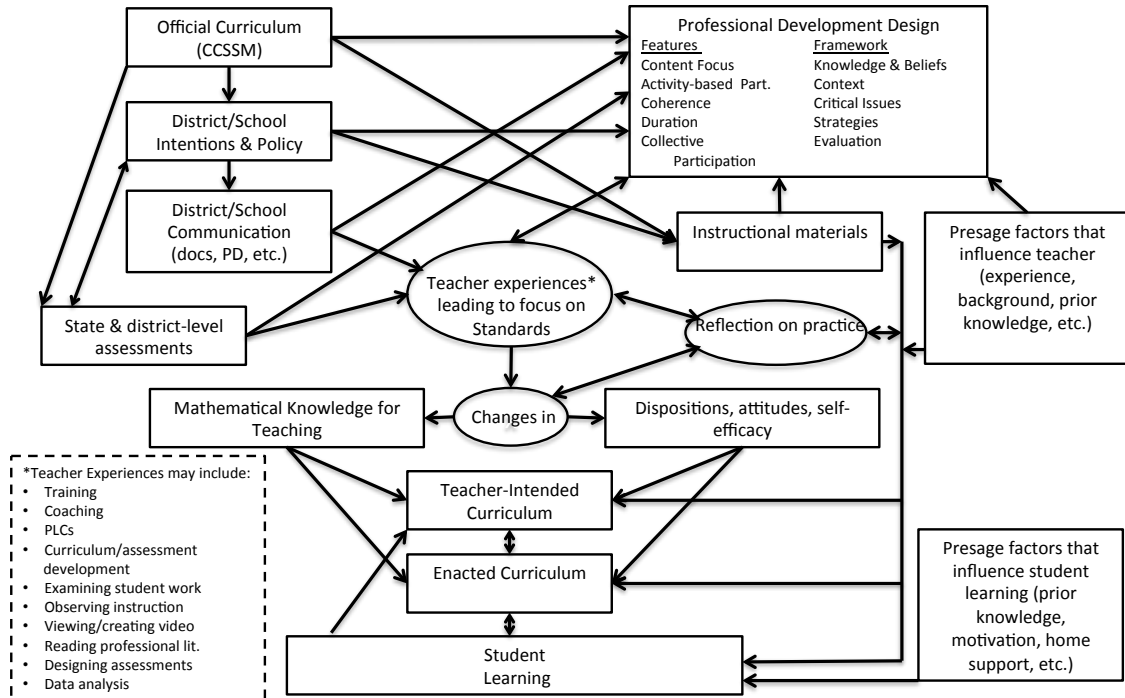


Figure 3. Theory of change.

This theory of change includes the following major sections, to be discussed further in Chapter 5.

- Content: The CCSSM appears in the upper left-hand corner as the primary content for the treatment in this study.
- Context: The organizational variables (district or school intentions and policy, district or school communication, and state or district assessments), as well as the instructional materials and teacher and student presage factor variables comprise the context of the study. Note that these variables were not directly studied for this dissertation, but each provided important insights into the detected changes.

- Treatment: The teacher learning experiences, including the professional development design and teacher reflection, make up the treatment of this study.
- Output—Teacher Knowledge: The changes in teachers' MKT, dispositions, attitudes, and self-efficacy compose the first of three outputs for this study.
- Output—Classroom Practice: The teacher-intended curriculum and the enacted curriculum comprise classroom teaching and learning, the second output. For the purposes of this study, the intended curriculum includes each teacher's planned intentions prior to classroom instruction, including his or her interpretation of guiding documents and instructional resources. The enacted curriculum centers on the various interactions among the teachers, their students, and the content during the enactment of instruction.
- Output—Student Learning: Student learning represents the third output for this study. This primarily included the analysis of district benchmark assessments, but also incorporated teachers' conceptions of student learning.

Note that in all its complexity, the only variable that directly impacts student learning is the enacted curriculum, which is composed of the various interactions among teachers, students, and content (Borko, 2004; Stein, Remillard, & Smith, 2007). Therefore, changes in teacher knowledge, skill, and disposition become critical if the CCSSM is to make its way from curriculum policy to classroom practice (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012).

## **Problem Statement and Purpose**

Speaking broadly, teachers lack the knowledge and support needed to fully implement the CCSSM content and practices (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). In the proposed theory of change, one sees that teachers, during the enactment of classroom instruction, are the primary link to student learning. Every other part of the diagram, including the CCSSM, district policy, and professional development, must be filtered through the teachers' conceptions and classroom instruction to impact student learning. Teachers are the primary decision makers in the planning and execution of classroom-level instruction. As has been seen throughout the reform efforts of the past, if teachers lack understanding of the contents and practices of these standards, implementation of the standards, as intended, will remain elusive (Confrey, 2007; Jardine et al, 2008; Kaufman & Stein, 2010; Lappan, 1997).

Therefore, this dissertation study was designed to examine the impact of a content-focused, activity-based, coherent, sustained, interactive professional development program focused on the CCSSM. It included mandatory participation of all teachers across one grade level in a single school district, with the intention of transforming teacher knowledge in such a way as to impact classroom implementation and, ultimately, student learning.

## **Research Questions**

In this mixed-methods study, randomly assigned experimental and control groups were compared using several data sets to answer the following questions.

1. What is the relationship between professional development for the CCSSM and teacher knowledge, skills, and dispositions?
2. What is the relationship between professional development for the CCSSM and classroom practice?
3. What is the relationship between professional development for the CCSSM and student learning?

### **Broader Impact**

The *Priority Research Agenda for Understanding the Influence of the Common Core State Standards for Mathematics* entreated that research be conducted to build the field's knowledge of CCSSM's impact on teachers and students (Heck, Weiss, & Pasley, 2011). Specifically, a call was made to research ways in which teachers respond to the CCSSM and the kinds of student learning opportunities that result from those responses. This study was created to examine a carefully designed course of study for teachers, helping them, first, to internalize the CCSSM curriculum they are to teach and, second, to embed their learning into classroom practice to positively impact student learning. This study will inform the field of ways in which teachers interact with the CCSSM, struggle with its content and implementation, and perceive the impact on their students' learning processes.

## CHAPTER 2

### LITERATURE REVIEW

The current educational landscape is replete with high expectations based on local, state, and national standards and policy. Increasingly, policymakers, administrators, and the public at large expect teachers to educate children to high standards, regardless of student background or economic status. With data pouring in from local, state, national, and international assessments, comparisons between schools, districts, states, and nations lead to even higher expectations (Klein et al., 2005). In addition, the literature widely recognizes teacher quality as one of the most important factors in student learning (Loucks-Horsley et al., 2010; Wei, Darling-Hammond, Adamson, 2010), though many elementary teachers find themselves poorly prepared to face the demands placed on them, especially in the area of mathematics.

Since the release of the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards of School Mathematics* (NCTM Standards) in 1989, mathematics reform efforts have focused on developing conceptual understanding through several processes including problem solving, communication, connections, and reasoning. However, for standards-based mathematics reform to become a reality, teachers need strong content knowledge as well as skills, behaviors, and beliefs that lead to changes in the classroom and, ultimately, higher levels of student understanding (Cobb & Jackson, 2011; Darling-Hammond et al., 2009; Loucks-Horsley et al., 2010). For teachers to gain the knowledge, vision, beliefs, and behaviors necessary for attaining high standards for all students, opportunities for professional development, in its many forms,

play a major role in transforming the way teachers do business (Hill, 2010; Spillane & Zeuli, 1999).

Unfortunately, research in the teacher professional development space reveals limited impact. Large-scale reports show that teachers do not participate in enough professional development to initiate or sustain long-term change (Darling-Hammond et al., 2009; Weiss, Arnold, Banilower, & Soar, 2001), and participation is even less prevalent for teachers working at schools in rural communities than for their counterparts working in urban and suburban schools (Chval, Abell, Pareja, Musikul, & Ritzka, 2008). According to the National Staff Development Council's 2009 report,

in education, professional learning in its current state is poorly conceived and deeply flawed ... It is time for our education workforce to engage in learning the way other professionals do—continually, collaboratively, and on the job—to address common problems and crucial challenges where they work. (Darling-Hammond et al., 2009, p. 2)

The opportunities to participate in effectively designed and meaningful activities that lead to systemic change, such as working collaboratively with colleagues and learning from mentors, occur far too infrequently. Instead, the prevalence of strategies shown to have little long-term impact, such as stand-alone workshops with no follow-up and little time investment, continue to dominate an already scant approach to professional development (Darling-Hammond et al., 2009; Loucks-Horsley et al., 2010).

For example, according to the National Schools and Staffing Survey, 90% of U.S. teachers reported participating in short-term conferences or workshops, whereas only 22% visited classrooms in other schools. In addition, although teachers typically need about 50 hours of substantial, focused professional development to improve instruction and student learning, 57% of the teachers surveyed reported receiving no more than 16

hours of content-specific professional development in the past year, and only 23% had received 33 hours or more. Furthermore, only 59% of teachers said their content-related training was useful, and fewer than half stated that the professional development they received in other areas was of much value to them (Darling-Hammond et al., 2009). In addition to direct professional development opportunities, the organizational structures needed to support and sustain change in teacher practice do not exist to the extent one would hope as evidenced by sporadic ongoing professional development, little to no follow-up opportunities, and lack of collaboration opportunities, all strategies that lead to change in practice (Darling-Hammond et al., 2009; Wei et al., 2010).

Interestingly, as the mathematics standards movement has gained in both scope and momentum, the quality of professional development has decreased. The number of content-based workshops and seminars has increased over the past decade. However, the opportunities for teachers to work collaboratively through activities such as observing and providing feedback to one another, working together on lesson planning and design, and spending large amounts of time developing their content and craft (e.g., greater than 50 hours) have decreased dramatically (Darling-Hammond et al., 2009).

This literature review focuses on teacher professional development regarding mathematics standards implementation. It begins with an examination of the literature on the standards-based mathematics movements on which the CCSSM was built. Then it explores the literature on the creation and implementation of professional development programs for mathematics reform. After an overview of the research on MKT, it addresses the research, and lack thereof, of the direct impact of professional development on teacher knowledge, classroom practice, and student learning.



## **A History of Mathematics Reform**

“If content standards are successful, they should permeate instructional practice” (Confrey, 2007, p. 44). Given the tenuous history of mathematics reform and the accompanying tensions between reformers and traditionalists, the timeless notion that the teacher plays a primary role in reform efforts has remained a central focus since the post-Sputnik era (Lappan, 1997). Although many studies conducted in the past few decades have described, and sometimes even judge, teacher quality and instructional materials resulting from standards-based policies, research on implementation impact remains limited at best (Confrey, 2007; Ferrini-Mundy & Floden, 2007). Though few broad conclusions can be drawn regarding the impact of mathematics standards on systemic improvement of mathematics education as a whole (Ferrini-Mundy & Floden, 2007; Klein et al., 2005; B. J. Reys et al., 2006), some general principles may be derived from a composite view.

### **Sputnik: The First Modern Mathematics Reform**

The years following World War II brought about increased attention on science, technology, engineering, and mathematics, leading to the establishment of the National Science Foundation in 1950 (Lappan, 1997). Soon thereafter, with the Soviet launch of Sputnik in 1957, all agreed that if the United States was to be competitive, increased attention must focus on preparing the next generation of mathematicians and scientists. This catapulted U.S. education, including mathematics, into the political spotlight like never before. Schools became the target of blame for teaching the wrong things in the

wrong ways, and curriculum development emerged as a policy issue (Marshall, Sears, Allen, Roberts, & Schubert, 2007).

The National Defense Education Act of 1958 declared that more adequate educational opportunities needed to be made available to students in U.S. schools. Curriculum development was removed from the hands of teachers and replaced with prepackaged texts and programs—thus, the “teacher-proof” curricula arrived on the scene along with “New Math” (Marshall et al., 2007). With a heavy emphasis on conceptual understanding and hands-on learning, it laid a foundation on which the future standards-based movement would build (Lappan, 1997). In addition, although curriculum development received the strongest emphasis, an underlying emphasis on increasing teacher quality in some of the NSF-supported projects was embodied through the creation of curriculum materials intended to support teachers in gaining content knowledge, improving instructional practices, and integrating formative assessment (Lappan, 1997).

However, teachers and parents alike struggled with the methods, citing that this new way of learning math did not look like “real math” (Jardine et al., 2008), and critics claimed that students were not learning the basic skills necessary for success in mathematics (Confrey, 2007; Lappan, 1997). It seemed that implementation had faltered at the classroom level; consequently, these efforts lasted little more than a decade as the NSF withdrew funding from this reform initiative in 1970 (Confrey, 2007). Moving into the 1970s, mathematics curriculum once again took a shift back towards curricula that lent itself to skills easily detected on competency testing (Confrey, 2007).

## **A Nation at Risk: The Standards-based Reform**

In 1983, the National Commission on Excellence in Education released a landmark document, *A Nation at Risk*. This report responded to the radical school reforms that had taken place in the late 1960s and 1970s, advocating a shift from basic skills mastery to the development of intellectual processes and higher-level thinking in all content areas (Marshall et al., 2007). The groundbreaking document most widely recognized as defining mathematics education reform is the NCTM Standards (NCTM, 1989, 2000).

During the 1990s, as standards-based reform took shape, the transformation of mathematics education was fraught with tension. Strong opposition to the NCTM Standards arose from those who believed that not enough emphasis was placed on arithmetic procedures (Confrey, 2007). Furthermore, teachers were not equipped to understand or carry out the changes, the new ideas about classroom practice were not well developed, resources were limited, professional development was unevenly distributed, and alignment between standards and tests was lacking. In addition, studies such as the Third International Mathematics and Science Study revealed that U.S. mathematics teachers' mathematical content knowledge was lacking, and that, in general, teachers continued in a business-as-usual manner, relying on traditional "teacher-proof" textbooks to teach mathematics as they had been taught to do (Confrey, 2007).

However, even with these and other struggles, the mathematics standards movement continued forward. Forty-seven states and the District of Columbia had adopted mathematics standards by 2000 (Klein et al., 2005). District administrators had put strong efforts toward implementing the changes suggested by the NCTM and various

NSF-supported curricula, albeit with mixed levels of understanding and depth of knowledge (Cohen & Hill, 2000; Spillane, 2004). At the same time, some experts questioned the vision of the standards movement, wondering if it would be able to live up to the vision of mathematical literacy for all and assessment that was broader than the economically efficient, educationally deficient use of standardized tests (Apple, 1992; Confrey, 2007).

### **No Child Left Behind: The Accountability-Based Reform**

No Child Left Behind (NCLB) carried strength that was absent in *A Nation at Risk*—rather than being a report or a game plan, it was law. This law touted accountability, excellence, standards, and school reform. These notions were not necessarily new, dating back to the Committee of Ten in 1892, the Woods Hole Conference in 1959, and *A Nation at Risk* (Marshall et al., 2007), but they carried weight like never before.

As states moved forward in their standards efforts, tensions arose between the contents of the standards and what had become the test-based accountability system. As Jack Jennings, President and CEO of the Center on Education, stated, “The problem with the standards-based reform is that it has become test-driven reform” (Jennings, 2012). Furthermore, although all 50 states implemented their individual state standards, researchers and policymakers alike lamented the discontinuity between state standards and the lack of standards alignment from state to state (Klein et al., 2005). However, many experts claim that the effort to quantify student learning resulted in the narrowing of mathematics instructional content and pedagogy (Ferrini-Mundy & Floden, 2007; Martone & Sireci, 2009; Ravitch, 2010). The efforts to quantify the teaching and learning

of mathematics reduced students' opportunities to learn and narrowed the curriculum based on items that could be measured on state-level, multiple-choice tests (Resnick et al., 2004, cited by Martone & Sireci, 2009).

### **Common Core State Standards: The Latest in Standards-Based Reform**

Upon reflection on the vast differences between state standards frameworks and state-level assessments, many concluded that perhaps a national framework would be in order (Klein et al., 2005; Marshall et al., 2007; Ravitch, 2010; B. J. Reys et al., 2006). In 2010, the National Governor's Association and the State Council of Chief State School Officers produced the CCSSM, as of April 2013, adopted by 45 states, Washington, DC, and three U.S. territories (Common Core State Initiative, 2013b). To ease the tensions from previous reform efforts, the teams working on the CCSSM included stakeholders who had, in the past, been at odds with one another, including mathematicians, educators, researchers, and policymakers (Common Core State Initiative, 2013a).

Since its publication, studies have been conducted to examine the claims of the CCSSM regarding focus, coherence, and rigor while examining the relationship between these new standards and the standards in top-performing countries, as well as with current U.S. state standards (Porter et al., 2011; Schmidt & Houang, 2012). Strong correlations have been found between the CCSSM and top-performing countries in terms of the number of topics covered per grade (focus) and the connection of topics across specific grade bands (coherence), suggesting that the CCSSM could positively impact U.S. students' achievement scores (Schmidt & Houang, 2012). However, the conclusions of this study, and others, hinge on the assumption that focused, coherent standards will define and determine enacted content in the classroom, a factor with no guarantees.

Another study compared the rigor of the CCSSM to various state-level standards documents using the Surveys of Enacted Curriculum, attending to topics covered at each grade level, and to categories of cognitive demand (memorize, perform procedures, demonstrate understanding, conjecture, solve nonroutine problems). This study found that the CCSSM represented a modest shift toward higher levels of cognitive demand as compared to the state-level standards, but that the state-level standards, when looked at individually, included major inconsistencies from state to state, with some being highly correlated and some showing low correlations (Porter et al., 2011).

Although these studies reveal that comparisons between the CCSSM and standards of high-performing nations and state-level standards are quantifiable, the authors' conclusions often pivot on issues of implementation. Certainly the advantages of having common standards across the United States deserve consideration: shared expectations, common foci within grade levels, efficiency and shared capacity for materials and assessment creation, and potential for increasing assessment quality (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). However, the degree of implementation at the classroom level will ultimately determine the success or failure of the CCSSM.

Much work remains to be accomplished prior to the full implementation of the CCSSM, and the fate of this latest reform effort has yet to be determined. As was true with the standards efforts in the past half century, the CCSSM in and of itself is nothing more than education policy outlining the *intentions* for mathematics content and practices. Creating instructional policy is simply the beginning—only within the context of classroom implementation will the potential offered by these standards live up to its

promise (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). Thus, an emphasis on change in classroom practice is pivotal, with professional development focused on teachers' CCSSM implementation being a primary conduit for such change.

### **Professional Development in Mathematics Education**

Throughout the various mathematics reform efforts of the past decades, teacher quality has remained a consistent concern. As seen throughout the historical account in the previous section of this literature review, issues regarding teachers' content and pedagogical knowledge were often mentioned. Throughout the many attempts at standards-based reform in mathematics education, the latest being the CCSSM efforts, experts have advised that teacher knowledge plays a central role in whether the standards will make an impact on student learning (Ball et al., 2008; Cobb & Jackson, 2011; Porter et al., 2011; Ravitch, 2010; Schmidt & Houang, 2012; Shulman, 1986). Professional development, in its many forms, plays a significant role in facilitating change in teachers' knowledge of the mathematics they teach and how they teach it. However, the literature in the professional development space often highlights the importance of program design and implementation. For professional development to be effective, attention must be given to how the standards are communicated, the learning-experience design and delivery, and the supported for teacher learning (Borko, 2004; Desimone, 2009).

### **Focusing on the Mathematics Standards**

Before diving into the frameworks and features for effective professional development design and delivery, the content warrants attention. In the case of the present study, the learning experiences focused on the content and pedagogy required to

implement the CCSSM as intended. The following conversation revolves around the CCSSM policy, as well as states' and districts' translation of the CCSSM in the form of curriculum maps, pacing, guides, and other support materials.

Regardless of the foundational documents for state-level standards (NCTM Standards, CCSSM documents, etc.), these curriculum documents represent policy adopted by the state, intended for implementation at the classroom level. However, translation from policy to practice occurs at many levels and with varying degrees of expertise. Spillane (2004) stated, “regardless of its resilience, standards-based reform initiatives face a familiar policy challenge—successful local implementation” (p. 4). The school district administration often serves as the intermediary between the statehouse and the schoolhouse, offering teachers tools such as curriculum materials, scope and sequence documents, and pacing guides. In fact, because district-level supervision and accountability structures play a much more direct role in teachers' work, teachers tend to pay more attention to district-level documents and assessments than to state-level policy documents (Hill, 2001; Spillane, 2004). However, these documents are only as true to the intentions of the policymakers as the district personnel who create them.

As state-level standards were being developed, local implementation of the standards became a focal point for some researchers (Cohen & Hill, 2000; Confrey, 2007; Spillane, 2004). For example, as district leaders attempted to translate policy into useful documents and classroom tools, the tools themselves did not always take on the meaning intended by the policymakers. Studies have revealed that as workgroups assemble district materials to support state-level standards, they frequently misinterpret the standards documents (Hill, 2001). In addition, varying levels of district-level curriculum designers'



expertise in mathematics may lead to wide discrepancies in the district-level support materials created for classroom use, resulting in various levels of implementation (Spillane, 2004). For example, in one study, an administrator who had a limited view of problem solving as simply solving story problems interpreted the standards in light of this interpretation, thus missing the spirit of the standard itself. At the same time in a neighboring school district, an administrator well versed in mathematics concept development paved the way for higher levels of standards-based instruction through district-written curriculum and support materials (Spillane, 2004).

Tendencies to misconstrue the intentions of policymakers, combined with poorly aligned standards and assessments, often leads to poorly constructed documents that mislead instruction (Confrey, 2007; Spillane, 2004). As Confrey (2007) noted, even in the presence of strong incentives and sanctions, mathematics practices only changed when the content was deeply understood by the teachers. Because teachers note that district efforts such as professional development, curriculum frameworks, and ongoing communication play a much stronger role in their mathematics instruction than do the policy documents themselves (Spillane, 2004), the need for high-quality district materials remains strong if change is to occur.

### **Designing Effective Professional Development Programs**

Professional development includes any activity intended to impact one's professional practice. In the context of education, this includes traditional notions of professional development, such as workshops, seminars, and courses, as well as activities such as lesson analysis, book clubs, online exchanges, staff meetings, professional reading, interactions with curriculum, reflection on practice, and content-based

conversations (Desimone, 2009; Guskey, 2000; Loucks-Horsley et al., 2010). Weaving together relevant, meaningful, coherent, curriculum-based professional development requires careful planning. Attending to the core features for professional development, as well as the elements of design and adult learning, increases the likelihood of impacting teacher knowledge in ways that will transfer to classroom practice and, ultimately, student learning. Following is a review of the literature specific to professional development for promoting standards-based mathematics reform.

**Theoretical framework for professional development.** The importance of well-designed professional development cannot be overstated, but the impact of such opportunities on changes in teacher knowledge, classroom practice, and student learning frequently goes unexamined beyond simple assessment of teacher reactions immediately following the experiences (Desimone, 2009; Guskey, 2000; Loucks-Horsley et al., 2010). Unfortunately, studies have shown that a majority of teachers participate only in the minimum amount of professional development required, and they are less than pleased with the impact of the experiences in which they participate (Darling-Hammond et al., 2009; Hill, 2009). This leads to reluctance to participate on the part of teachers and lack of impact on the side of providers. Far too often, teachers' professional development opportunities fail to transfer deep mathematical understanding into classroom practice, with teachers simply replicating the training activities at the surface level rather than demonstrating changes in behaviors and beliefs that transform classroom practice (Hill, 2008).

In 2009, Desimone reviewed dozens of professional development studies, making the case that the professional development impact studies, when viewed as a whole,

reveal a set of core features and a common conceptual framework that warrant future study in this field. Pictured in Figure 4, her framework demonstrates how professional development and student learning are only indirectly connected, with changes in teacher knowledge and instruction serving as mediating variables between the two.

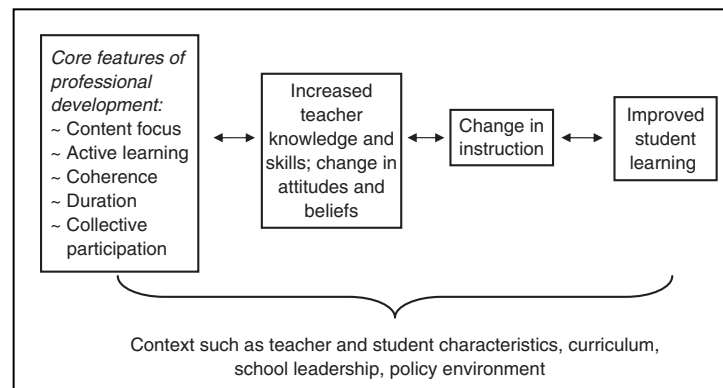
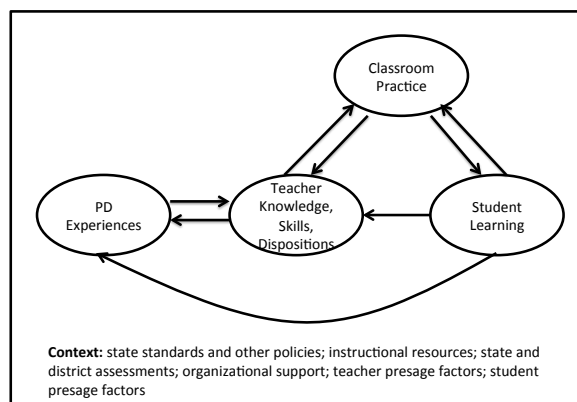


Figure 4. Desimone's theoretical framework.

From "Improving Impact Studies of Teachers' Professional Development: Toward Better Conceptualizations and Measures," by L. M. Desimone, 2009, *Educational Researcher*, 38, p. 185.

As a model for studying the effects of professional development on teachers and students, this framework covers the major factors requiring examination. However, with an emphasis on attending to student data to inform decision making, perhaps this framework would be enhanced by including feedback loops from *student learning* back to *professional development* and *teacher knowledge* to acknowledge the impact that student learning data have on both professional development design and teacher reflection on classroom instruction (J. Middleton, personal communication, October 21, 2010). With these additions, this adapted framework (Figure 5) summarizes the major sections found in the theoretical framework introduced at the end of Chapter 1.



*Figure 5.* Theoretical framework for professional development. Adapted from “Improving Impact Studies of Teachers’ Professional Development: Toward Better Conceptualizations and Measures,” by L. M. Desimone, 2009, *Educational Researcher*, 38, p. 185.

Within her framework, Desimone directly addresses the importance of professional development in policy implementation, which includes the implementation of state-level mathematics standards (Desimone, 2009). Beyond aligning with school, district, and state-level goals for mathematics standards, quality professional development also involves opportunities for teacher collaboration, active engagement in the learning process, interaction with mathematics content, and ongoing opportunities to develop beliefs, attitudes, knowledge, and skills over time (Cobb & Jackson, 2011; Cohen & Hill, 2004; Desimone, 2009; Hill, 2010).

**Content focus.** Maintaining a focus on the mathematics subject matter content and how students learn within the context of professional development has garnered much attention in the past 2 decades (Ball, Lubienski, & Mewborn, 2001; Borko, 2004; Cohen & Hill, 2000; Heck, Banilower, Weiss, & Rosenberg, 2008; Spillane & Zeuli, 1999). With the advent of the CCSSM, experts are already calling for professional development that focuses on the content standards and mathematical practices outlined in the document. Without the opportunity to understand the meaning of the content and its

implications on classroom practice, there is little chance that the CCSSM contents will impact student learning as hoped (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). The pedagogical knowledge required to understand the shifts in focus, coherence, and rigor inherent within the CCSSM eludes many teachers (National Governors Association for Best Practices & Council of Chief State School Officers, 2010), including the specialized content knowledge (SCK) necessary for developing a conceptual understanding in students. Transforming educators' beliefs about and behaviors in implementing the profound principles of fundamental mathematics will require intensive opportunities to embed pedagogical content knowledge into their repertoire, primarily through professional development activities.

*Active learning.* The term *active learning* is used here to describe opportunities in which participants interact with one another, such as analyzing student work, planning with colleagues, or participating in a discussion, as opposed such passive tasks as listening to lectures (Borko, 2004; Desimone, 2009; Ferrini-Mundy et al., 2007). To avoid confusion with the notion of active learning in the cognitive sense, the term *activity-based learning* will be used synonymously throughout this paper.

Stated simply, what is good for the student-learning process is good for the teacher-learning process—after all, within the context of professional development, teachers are learners. For example, just as with children, activity-based learning opportunities centered on specific tasks (e.g., a mathematics problem to solve) have been noted to provide context and, to a great extent, define what students learn (Borko, 2004; Loucks-Horsley et al., 2010; Spillane, 2004). Mathematics tasks that engage activity-based learning can be structured for use in workshop settings to provide contexts in

which teachers learn to improve curricular coherence based on state-level standards rather than simply viewing the standards as a checklist of items to be covered (Ferrini-Mundy et al., 2007). These tasks may come in a variety of formats. In one study, three such experiences included (a) solving mathematics problems that are typical for students at the participants' assigned grade levels followed by discussing the sophistication of the student problem-solving strategies across the grades, (b) listing the objectives taught at participants' assigned grade levels for a given concept and then examining the learning progressions as they should be taught versus what they look like in practice, and (c) solving actual problems and then discussing the implications for instruction (e.g., vocabulary, models, measurement tools, etc.). In this formative study, researchers found that by engaging in such tasks, teachers' content knowledge and their knowledge about how students learn was impacted, with the goal of developing curricular coherence in the classroom setting. (Ferrini-Mundy et al., 2007).

***Coherence.*** As emphasized in the CCSSM, *coherence* has been widely recognized as an essential element to the standards-implementation movement, with an emphasis on developing coherent mathematical understanding within single grade levels as well as across grade levels. However, in the professional development context, coherence is described as “the extent to which teacher learning is consistent with teachers' knowledge and beliefs” (Desimone, 2009, p. 184). Because the CCSSM emphasizes shifts in classroom practice, primarily through implementation of the mathematical practices and the emphasis on conceptual development, many experts express concern regarding teachers' abilities to implement the standards (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). This concern focuses on

the lack of coherence between teachers' current knowledge and beliefs regarding mathematics and the teaching of mathematics under the intentions in the CCSSM.

An additional and important aspect of coherence includes the consistency with which school, district, and state policies (in this case, the CCSSM) are aligned and included within the context of professional development (Darling-Hammond et al., 2009; Weiss et al., 2001). This also includes the notion that reform efforts are most likely to impact classroom practice when there is consistency between and among other school and district initiatives concurrently being implemented (Kazemi & Hubbard, 2008). If teachers must attend to too many initiatives at once, they will be distracted from the depth of instructional implications inherent in the work at hand—in this case, the changes necessary for successful implementation of the CCSSM content standards and mathematical practices.

***Duration.*** Change in teacher knowledge and practice requires that professional development activities take place over long durations as opposed to one-time workshop settings (Desimone, 2009). This includes both a large number of hours, preferably 30–100, as well as a long period of time, optimally 6 to 12 months (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Other syntheses have stated that the strongest positive effect is seen in programs that offer more than 50 hours of professional development (Darling-Hammond et al., 2009).

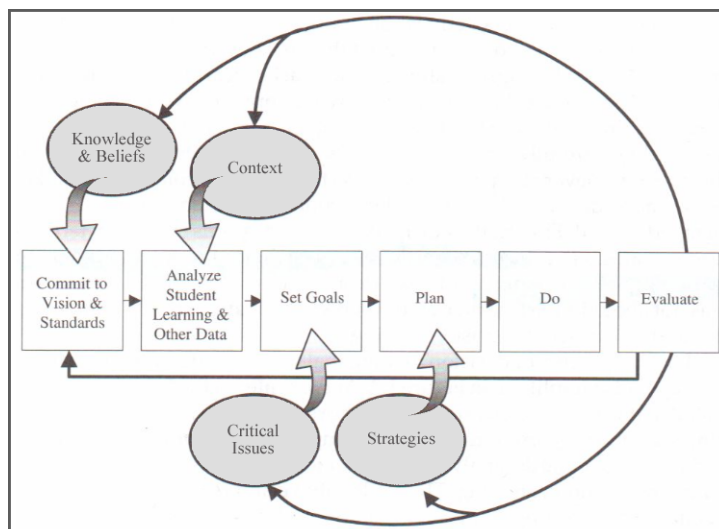
***Collective participation.*** Collective impact emphasizes that learning is a social endeavor, and greater impact is made when educators attend together and interact with one another toward the learning goals. Impactful professional development is aligned to district goals (coherence) and builds strong working relationships among teachers

(Darling-Hammond et al., 2009). Breaking down professional isolation while promoting collaboration among teachers from the same school or grade level maximizes dynamic learning (Borko, 2004; Desimone, 2009; Loucks-Horsley et al., 2010).

**Professional development design model.** Professional development efforts that lead to changes in teachers' practice and in the larger school culture are not inherent in discrete events such as independent workshops and seminars; rather, they are found in a plethora of ongoing experiences and interactions (Darling-Hammond et al., 2009; Desimone, 2009; Loucks-Horsley et al., 2010). These experiences include multiple contexts, both formal and informal, such as hallway conversations, teacher–student discourse, coaching, mentoring, reflection on teaching, book clubs, teacher networks, study groups, classroom and student observations, online venues, curricula design or evaluation, journal articles, examination of state assessments, and participation in policy implementation (Desimone, 2009).

When designing professional development of any kind, the ultimate goals include changes in teacher knowledge that lead to positive impact on classroom instruction and higher student achievement. Of course, as noted in the theoretical framework in the previous section, the relationship between professional development and student learning is mediated by changes in teacher knowledge and classroom practice, among other variables (Desimone, 2009). Therefore, professional development organizers may find it helpful to use a specified structure to guide them in careful decision making during the development, implementation, and evaluation of the professional development design to ensure attainment of the goals at hand. Loucks-Horsley et al. (2010) proposed such a framework that includes the components in Figure 6.





*Figure 6.* Professional development design framework.  
 From *Designing Professional Development for Teachers of Science and Mathematics* (3rd ed.), S. Loucks-Horsley, K. C. Stiles, S. Mundry, N. Love, & P. W. Hewson, 2010, Thousand Oaks, CA: Corwin, p. 18.

**Inputs.** While moving through the professional development design process, this framework suggests that one consider several inputs that ideally contribute to planning and implementation. The first focuses on the facilitators' *knowledge and beliefs* about the specific content, relevant professional development, and adult learning. Selecting a facilitator who is knowledgeable about learners and learning, teachers and teaching, the content being covered, adult learning theory, and the change process is vital to the quality of the professional development (Borko, 2004). Achieving the vision and goals hinges on the knowledge and beliefs of the facilitator. One crucial element to look for in a facilitator is the ability to scaffold learning that is concurrently relevant to classroom implementation while building the knowledge base over time (Loucks-Horsley et al., 2010). Another important characteristic takes into account the facilitator's ability to establish credibility and rapport with participants (Borko, 2004). These characteristics are not unlike the qualities of a good classroom teacher.

The second input, the *context* of the professional development, plays an important role in the creation of quality programs. The context includes such factors as community demographics, student data, and teacher knowledge and conceptions. Studying the available data allows one to plan professional development that is (a) relevant to the students and their learning needs; (b) inclusive of the teachers and their learning needs; (c) adapted for the curriculum, instruction, and assessment practices within the targeted community; (d) sensitive to local organizational structure; (e) attentive to developing local leadership; (f) focused on national, state, and local policies; and (g) aware of the families and communities beyond the classroom (Loucks-Horsley et al., 2010). According to the model, these factors emerge as one analyzes available data, and they provide input for the professional development planning phase.

Third, *critical issues* to be considered include building capacity for sustainability, scheduling, developing leadership, ensuring equity, building a professional learning culture, and scaling up (Loucks-Horsley et al., 2010).

Fourth, selection of *professional development strategies* that lend themselves to accomplishment of the goals and outcomes as well as work within the confines of the context and critical issues should be considered. The selected strategies may include activities, techniques, ideas, or materials that initiate teacher learning and, in turn, develop content knowledge and improve understanding of student learning. When woven together over time to provide support and scaffolding for participation in practice-based learning, these strategies will prove successful (Loucks-Horsley et al., 2010). This input lends itself directly to the notion of *activity-based learning opportunities* previously discussed in the theoretical framework (Desimone, 2009). Often, these interactive

opportunities include activities such as engaging in problem solving, analyzing student work, developing case studies, interacting through online networks, observing or coteaching demonstration lessons, examining written materials, participating in focused dialogue on relevant content, and reflecting on practice (Loucks-Horsley et al., 2010). Examples of activity-based learning opportunities shown to increase the likelihood of teacher learning and classroom implementation may also include the use of sharing and analyzing a video of classroom instruction (Borko et al., 2008) and the use of carefully planned teacher learning tasks that encourage teacher discourse within and across grade levels (Ferrini-Mundy et al., 2007).

***Process.*** The main process, designated by the six rectangles in the center of Figure 6, states that one should first *commit to vision and standards*. When focusing on mathematics reform, those standards include the state-level standards (in most states, the CCSSM). In this case, a full commitment to both the content standards and the mathematical practices remains critical to change in teachers' understanding of the profound fundamentals of the CCSSM as well as change in classroom practice (Cobb & Jackson, 2011; Spillane, 2004). Furthermore, as previously mentioned, the knowledge and beliefs of the facilitator are key to casting a vision for standards-based reform.

When *analyzing student and other data*, consideration of the context of the professional development is warranted, including the content, standards, policy environment, district support systems, organizational structure, teacher and student characteristics, among others (Desimone, 2009; Loucks-Horsley et al., 2010). Such factors as the teachers' background and content knowledge, their experience levels, alignment of district-adopted resources, and availability of leadership support play an

important role in professional development design. This context also includes available data on student learning and current teaching practices, so that the professional development can be differentiated for the participants (Chval et al., 2008; Guskey, 2000).

When the time comes to *set goals* for the professional development program, these goals should specify how the program will impact teacher knowledge, classroom implementation, and student learning (Ball et al., 2008; Hill, 2008). These goals should also consider the critical issues mentioned above, paying particular attention to the teachers' prior knowledge and the support structures in place to maintain coherence between the professional development and other school and district initiatives (Loucks-Horsley et al., 2010).

During the *plan* and *do* phases, the planning team investigates strategies that fit within the confines of the context and promote the professional development's goals and outcomes. This also includes producing and implementing a coherent plan that weaves the learning opportunities together to optimize their impact on teacher learning. Spacing the training sessions out to give participants opportunities to experiment with newly learned strategies maximizes participant learning (Darling-Hammond et al., 2009). Once again, programs that include 30–100 hours of training over the course of 6 to 12 months provide the greatest results (Yoon et al., 2007).

*Evaluation* of professional development has long been criticized for its lack of coherence and focus on evaluating all levels of impact (Borko, 2004; Desimone, 2009; Guskey, 2000). This topic will be discussed in detail later; for now, comprehensive professional development evaluation includes more than simple participant reactions to the professional development opportunities. It also incorporates instrumentation to detect

changes in participant knowledge, classroom implementation, and student learning. If possible, evaluating the varied levels of organizational support will also provide valuable feedback to all constituents (Guskey, 2000). While using this model to design and implement professional development, layering the features from Desimone's (2009; Figure 5) professional development framework will facilitate elements shown to enhance standards-based mathematics professional development. Researchers familiar with the CCSSM have called for training *focused on content and practices* (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). Participants benefit from engagement in *activity-based learning opportunities* that include opportunities to develop ideas through interaction and discourse (Hochberg & Desimone, 2010). *Coherence* with national, state, and local policy (Cohen & Hill, 2000) and integration of standards with curriculum and assessment will greatly increase the chances of successful transfer from the professional development setting to student learning (Hill, 2007b; Hochberg & Desimone, 2010). Professional development that is sustained over a *duration* of time increases teacher knowledge and the likelihood of classroom implementation (Cohen & Hill, 2000; Hochberg & Desimone, 2010). Finally, both Desimone's theoretical framework and the Loucks-Horsley design model emphasize the importance of *collective participation* to maximize teacher learning (Borko, 2004; Desimone, 2009; Loucks-Horsley et al., 2010).

### **Providing Organizational Support**

Beyond the importance of effectively communicating state-level standards to teachers and offering quality professional development opportunities, successful

standards-based reform efforts also include elements of organizational support including elements of leadership, coherence, and logistics.

**Leadership.** Upon examination of what teachers attend to when implementing reform-based mathematics and science standards, Spillane (2004) found that district-level materials and assessment play a much larger role in mathematics-standards implementation than state-level documents due to the supervisory and accountability roles that districts play in teachers' work. These district-level materials include pacing guides, scope and sequence documents, alignment records, and curriculum materials. Furthermore, the degree to which district-level policymakers possess expertise in the various aspects of MKT (content, pedagogy, students, curriculum, etc.) tends to determine the degree to which those district materials align with the state or national standards' intentions (Spillane, 2004).

In addition, studies have shown that the support of knowledgeable building-level administration (e.g., principals) also has a profound impact on the level of teacher participation in and implementation of standards-based methods and strategies gleaned from professional development experiences (Heck et al., 2008). Likewise, strong instructional leadership with expertise in standards-based mathematics makes a difference in implementation at both the district level (Spillane, 2004) and at the school level (Coburn & Russell, 2008; Kaufman & Stein, 2010). A common vision, clear direction, and coherent implementation strategies play strong roles in increasing the likelihood of maximizing teacher sense making of the mathematics standards and the subsequent transformation of classroom practice.

Standards-based professional development programs that include opportunities for district- and building-level leaders increase the likelihood of successful implementation of standards-based methods and strategies. Such training informs leaders of what to expect in the classroom, increasing alignment between their supervisory and mentoring roles and the changes in teacher knowledge, skill, and implementation encouraged through professional development (Spillane, 2008).

**Coherence.** Several studies refer to the need for alignment between standards, curriculum, and assessment (Hill, Ball, & Schilling, 2008; Loucks-Horsley et al., 2010). Although teachers may attempt to bring these three together, district-level policies tend to dictate and have the power to coordinate these efforts (Spillane, 2004). Beyond the alignment of these three broad categories, districts and schools should coordinate professional development programs to incorporate coherence on several other levels, including professional development programs that emphasize connections between (a) mathematics content and pedagogy; (b) various teacher learning opportunities; (c) professional development contexts at the district, school, and classroom levels; and (d) student learning and teaching practice (Kazemi & Hubbard, 2008). In addition to content coherence, attending to scheduling and time commitments allows teachers ample opportunity to put new learning into practice while continuing to develop their understanding over time (Loucks-Horsley et al., 2010).

As previously mentioned, minimizing the number of initiatives competing for teachers' attention to maximize standards-based classroom practice builds coherence of purpose within and between professional development opportunities (Desimone, 2009). For example, if a district working towards standards-based mathematics reform

simultaneously implements additional, unrelated initiatives (e.g., simultaneous reform efforts in mathematics instruction, ESL strategies, and behavior management), teachers' divided attention will confound all efforts (Kaufman & Stein, 2010).

**Logistics.** District policies that encourage professional development features such as active learning opportunities, duration, collective participation, and formats such as teacher networks and study groups lead to greater implementation of mathematics reform efforts (Desimone, 2009; Desimone et al., 2002; Loucks-Horsley et al., 2010). When designing opportunities for teacher learning, such management and implementation strategies as aligning standards and assessments, involving teachers in the planning process, evaluating teacher needs and conceptions, and collaborating with other district efforts increase the quality and effectiveness of the teachers' learning (Desimone et al., 2002). Organizational support at both the district and school levels also impacts professional relationships and conversations at the school level. An emerging focus of study looks at how social network patterns are impacted by professional development design. For example, "experts" emerge through professional conversations, and teachers and administrators begin to consult with them more often, even outside the professional development setting. Because school leaders mediate district policy, either positively or negatively, developing robust routines for ongoing content-based professional conversations between principals, coaches, and teachers leads to changes in teacher understanding and implementation of reform efforts (Coburn & Russell, 2008).

Furthermore, district and school leaders can facilitate standards-based teacher learning by providing the logistical structures needed: coordination, scheduling, materials, and so on. An additional and often overlooked issue centers on the notion of



volunteerism (Desimone, 2009). Often, those educators most in need of development are the least likely to volunteer for participation in such opportunities. When standards-based professional development is required for all teachers, different training and support strategies may be necessary for teachers who are reluctant or resistant to change as opposed to those who voluntarily attend sessions encouraging changes in beliefs and behaviors. Therefore, not only must leaders require all teachers to participate in the development program, but they must also offer differentiated approaches within the program.

Districts and schools that pay attention to social-network structures and build capacity for collective learning increase the likelihood that standards-based methods and strategies will be implemented (Coburn & Russell, 2008; Cohen & Hill, 2000; Kazemi & Hubbard, 2008). Additionally, professional development programs that offer well-defined, goal-oriented, systemic mentoring and coaching opportunities, typically organized at the district level, result in moderate increases in teacher implementation and small but significant increases in student achievement (Wallace, 2009).

### **Evaluating Professional Development Impact**

Over the past 2 decades, professional development has been measured primarily through observation, interviews, surveys, and questionnaires, resulting in a myriad of disconnected data. Furthermore, these methods have been widely criticized for falling short of offering cohesive, strong evidence that change has occurred in teacher knowledge, classroom instruction, and student learning (Borko, 2004; Desimone, 2009; Guskey, 2000; Hill, 2008; Hochberg & Desimone, 2010; Kazemi & Hubbard, 2008; Wallace, 2009). Opportunities for teacher learning about the content and pedagogy

inherent in state-level mathematics standards play a strong theoretical role in classroom practice and are, at the very least, indirectly associated with student learning (Cohen & Hill, 2000). Evaluation is critical in determining the degree to which professional development accomplishes its goals as well as which aspects provide the most impact.

For example, a literature review by Kazemi and Hubbard (2008) concluded that, too often, professional development research and evaluation is unidirectional, focusing only on teacher actions and reactions to the actual training sessions. They noted that after the conclusion of many professional development programs, follow-up observations reveal a wide range of implementation, with some teachers exhibiting major changes in practice, whereas others show almost no change at all. These authors challenged researchers and evaluators to examine what teachers learn both during and after professional development, with an emphasis on making sense of primary artifacts, depictions, and enactments (e.g., teachers studying student work, teachers studying cases, enactment of routine activities to provide practice and reflection). This is but one example of ways in which researchers are attempting to address the shortcomings of professional development research.

Guskey's levels of professional development evaluation provide a useful framework for research in this space (Borko, 2004; Guskey, 2000). This hierarchy includes five levels:

1. participants' reactions (as mentioned above);
2. participants' learning (e.g., changes in teacher knowledge and skill, changes in teachers' dispositions);
3. organizational support and change;

4. participants' use of new knowledge and skills (e.g., change in instruction); and
5. student-learning outcomes.

Although Guskey designed this hierarchy primarily for practitioner evaluation purposes, researchers have also used these levels in designing multisite research evaluations of standards-based mathematics professional development programs (Abell et al., 2007; Borko, 2004; Guskey, 2000). Regardless of its use, this hierarchy challenges professional development evaluators to move beyond the mere opinions of the participants toward using measures to examine each program's effects on the acts and results of teaching and learning.

In sum, layering the research on professional development design with Guskey's (2000) evaluation hierarchy provides a foundation for detecting the impact of standards-based professional development on teacher knowledge, classroom practice, and student learning. The use of quantitative measures, such as observation protocols and assessments of teacher and student knowledge, and the qualitative methods more commonly used in the literature will provide a broader picture of a treatment's impact, a call often made in the research literature (Desimone, 2009; Guskey, 2000; Loucks-Horsley et al., 2010; Spillane, 2004).

### **Teacher Knowledge of Mathematics Content and Pedagogy**

The previous sections of this review focused on the dissertation study's treatment and content: professional development based on the CCSSM. Before attending to the impact studies for standards-based professional development, a review of the literature on teacher knowledge specific to mathematics content and teaching is in order. Professional development that promotes shifts in teachers' content and pedagogical knowledge for

mathematics-standards implementation requires attention to current theories regarding MKT and adult-learning theory.

### **Mathematical Knowledge for Teaching**

Building on Shulman's (1986) notion of pedagogical content knowledge, Ball and colleagues have developed a practice-based theory regarding MKT (Ball et al., 2001; Ball et al., 2008; Hill, 2010; Hill & Ball, 2004). Over the past decade, several studies have been conducted to flesh out the MKT categories encapsulated in this emerging theory, including work focused on developing an instrument for measuring teachers' MKT, the *Learning Mathematics for Teaching* (LMT) scales (Hill, 2007a; Hill, Ball, & Schilling, 2004).

Looking at Shulman's original work, teacher knowledge can be arranged into seven categories:

- content knowledge;
- general pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers;
- pedagogical content knowledge, that special amalgam of content knowledge that is uniquely the province of teachers, their own special form of professional understanding;
- knowledge of learners and their characteristics;

- knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and
- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (Shulman, 1987, p. 8).

Shulman (1987) went on to explain that pedagogical content knowledge most likely represents the body of knowledge that sets a teacher apart from the general population. Pedagogical content knowledge contains the unique blend of content and pedagogy to provide insight into how to organize and represent ideas in ways most suitable for targeting learners' interests and abilities.

With the goal of using an empirical approach to understand the content knowledge needed for teaching mathematics, Ball and colleagues (2008) analyzed studies of teaching practice to understand the nature of MKT. Through this work, they developed a framework that includes six domains grouped into two categories, subject matter knowledge and pedagogical content knowledge. (Ball et al., 2008). Figure 7 illustrates their hypothesized framework. Because these six domains were used extensively in this dissertation's qualitative analysis, the following paragraphs describe them briefly. Note that a more detailed list of descriptors for each domain appears in Appendix A.

*Common content knowledge (CCK)* includes the mathematical knowledge and skill used in a wide variety of settings and is not unique to teaching. Teachers may access CCK when working with students, but it includes concepts and skills that would also be commonly used outside of the education field. Examples of CCK include ideas such as

knowing a fraction that appears between  $1/3$  and  $2/3$ , knowing that a square is a special kind of rectangle, and knowing that  $0.01 = 1/100 = 1\%$ .

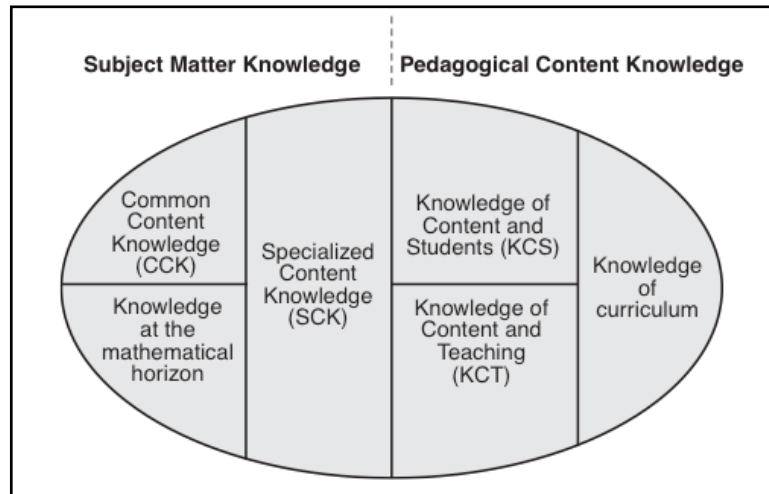


Figure 7. Mathematical knowledge for teaching diagram.  
From “Content knowledge for teaching: What makes it special?” by D. L. Ball, M. H. Thames, and G. Phelps, 2008, *Journal of Teacher Education*, 59, p. 403.

*Specialized content knowledge* consists of mathematical knowledge and skills that are unique to teaching. Examples of SCK include being able to explain why, when you multiply by 10, you “add a 0;” knowing which representations best illustrate operations with fractions; and whether a nonstandard solution method would work in all cases.

*Knowledge of content and students (KCS)* combines knowledge of students and knowledge of mathematics. Examples of KCS include knowing common student misconceptions, anticipating the difficulty level a specific problem will present for students, and being able to interpret students’ emerging thinking.

*Knowledge of content and teaching (KCT)* combines knowledge of teaching with knowledge of mathematics. Examples of KCT include discerning different instructional models for place value and knowing how to use them effectively, choosing effective examples, and sequencing instruction.

*Knowledge of content and curriculum (KCC)* contains notions similar to Shulman's work, which focused on knowledge of the materials and resources teachers use as "tools of the trade." This research team placed KCC under pedagogical content knowledge based on the continue work of Shulman's research team, noting that this placement may need adjustment as further research reveals the connections between the categories.

*Horizon content knowledge (HCK)* encompasses knowledge of how mathematics topics are related to one another both within and across grade levels. As with KCC, the research team temporarily placed HCK under subject-matter knowledge until further research can be implemented to determine if that placement is correct.

Several issues arise from this body of research, all of which continue to be investigated. First, because of the nature of practice-based theory, variability reveals itself in situations, such as where to categorize a student error analysis. One teacher may identify the error mathematically (SCK), whereas another may identify it as a common student misconception (KCS). Second, the diagram may lead one to believe that the domains are statically distinct; however, they may very well be continuous in nature. For example, where does CCK fall off and SCK begin? This leads to a third issue, involving concerns regarding the precision of each category's definition. Ball et al. (2008) confessed that their categories may not even be correct. However, this work, which focuses on the act of teaching, provides a critical starting point for investigating teacher knowledge as it develops in the professional development setting.

## **Four Notions of Adult Learning**

Although the MKT model is the primary focus for teacher knowledge in this study, a few additional principles regarding how adults learn impact the theory of change model, specifically addressing the notion of “changes” in teachers’ mathematical knowledge, beliefs, and conceptions.

**Cognitive processing.** Teacher practice is often resistant to mathematics reform principles (Cohen & Ball, 1990). There is often a mismatch between the intended, implemented, and attained curricula (Handal & Herrington, 2003) as teachers filter new policy through their old lenses of practice (Ferrini-Mundy & Floden, 2007). Spillane (2004) argued that teachers must go through cognitive shifts similar to what Piaget described for students, including the processes of assimilation and accommodation, in order to make sense of standards-based mathematics teaching.

The cognitive processes of assimilation and accommodation must take place as teachers learn or relearn their notions of mathematics and pedagogy for these new structures (Spillane, 2004). Often, even when teachers claim to embrace reform strategies, further classroom investigation reveals a lack of true understanding (Cohen & Hill, 2000; Spillane, 2000, 2004). Therefore, providing teachers with opportunities to develop their own conceptual understanding over time in a variety of contexts encourages higher levels of learning. Deep thinking and targeted discourse become critical for changes in understanding and practice aligned with the content at hand. “Policies that press radically new ideas require more complex cognitive shifts ... they demand that district policymakers and teachers change their existing knowledge scripts” (Spillane, 2004, p. 179). This implies that if teachers lack opportunities to grapple with new ideas



presented in the CCSSM, true implementation remains highly unlikely (Cobb & Jackson, 2011).

**Situated cognition.** Researchers have theorized that situated cognition plays a critical role in professional development, as well. Facilitators and teachers interact with one another as well as with the content at hand. Borko (2004) stated that “situative theorists conceptualize learning as changes in participation in socially organized activities, and individuals’ use of knowledge as an aspect of their participation in social practices” (p. 4). Changing one’s way of thinking requires social interaction as well as individual reflection as one grapples with new ideas. In the mathematics education context, such change is difficult: One must often unlearn and relearn both the mathematics content and the pedagogical structures that lead to reform-based teaching (Handal & Herrington, 2003). Many teachers have adopted this view as a guide for their classroom instructional environment, noting that their students learn best when they have opportunities to interact with others while engaging in problem solving situations. The primary emphases of reform-oriented mathematics instruction include opportunities for conceptual development and discourse, and this notion serves the learning of adults as well as that of children (Desimone, 2009).

**Beliefs regarding mathematics curricula.** Shifts in understanding may also be impeded by the belief systems to which teachers adhere. Values, emotions, and self-image all play roles in changing behavior (Spillane, 2004). As school systems move forward in standards-based teaching and learning, attending to teachers’ beliefs regarding the intended, implemented, and attained curricula remains critical; deep, meaningful instructional change will only occur where teacher beliefs align with the intent of the

standards (Handal & Herrington, 2003). Quite often, shifts in practice occur only at a surface level, not really going deep into *sense-making*, as emphasized in the CCSSM. “Traditional teaching” is often viewed by teachers as easier than methods requiring progressive approaches, especially in cases where teachers lack exposure and exemplars of reform strategies. Such teacher beliefs often get in the way of systemic reform efforts.

For example, when teaching in different bases became popular in the 1960s, many teachers became focused on student proficiency in operating in different bases rather than guiding the students through deep understanding of the significance of grouping structures within place value (Handal & Herrington, 2003). In this case, teacher practice changed through the introduction of new activities, but only surface-level instructional shifts took place as the teachers did not fully grasp the connections between the activity and the meaning behind the activity.

**Conceptions of need.** Teachers’ conceptions of their own needs, as well as their beliefs about mathematics content and how children learn mathematics, impact the way they engage with professional development experiences (Handal & Herrington, 2003). In one large-scale survey (Cohen & Hill, 2000), teachers claimed to embrace standards-based reform. However, when questioned further, they held onto elements of conventional mathematics teaching such as teaching computation using traditional methods rather than developing students’ conceptual understanding for numerical operations. These beliefs can hinder the efforts of professional development aimed at mathematics reform. In fact, many professional development opportunities fall short of their goals because they neglect teacher background, knowledge, conceptions, beliefs, and attitudes (Chval et al., 2008; Loucks-Horsley et al., 2010). Furthermore, even the

conceptions between professional development facilitators and the participants vary, resulting in mixed results (Park Rogers et al., 2007).

**Need for professional development.** Therefore, teachers need opportunities to make sense of the content and pedagogy presented within the standards. When surveyed, teachers often claim that they agree with the principles of the standards, but they are unable to implement them due to the lack of organizational support, the lack of training, and the realization that the standards are much more difficult to implement than they had been led to believe (Handal & Herrington, 2003). As written resources become available to support teachers in their CCSSM efforts, professional development may become even more necessary. Research has shown that sustained and intensive professional development is more likely to have an impact on teacher knowledge than curriculum materials alone and should be embedded into the work of the teacher (Schoenfeld, 2002). That said, professional development centered on the curriculum materials to be used in the classroom has been shown to increase student achievement (Cohen & Hill, 2000).

Emphasis on teacher training emerged as a landmark of many of the post-Sputnik-era curricula (Lappan, 1997), and the NCTM Standards reemphasized the need to increase teacher content and pedagogical knowledge (NCTM, 1989, 2000). With the advent of the CCSSM, researchers studying the focus, coherence, and rigor of the standards concur that large-scale plans for major shifts in teacher understanding and practice must take place or the intentions of the CCSSM will remain nothing more than policy (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012).

## Impact Studies of Professional Development for Mathematics Standards Reform

This final section focuses on impact studies conducted to discern the effectiveness of professional development for standards-based mathematics reform on teacher knowledge, classroom practice, and student learning. Although most studies have focused on one or more of these variables, several also focused on the relationship between organizational support and its impact on standards-based mathematics reform. The revised theoretical framework for professional development appears once again in Figure 8 as a reminder that the impact of professional development experiences on student learning is mediated by changes in teacher knowledge and classroom practice (Desimone, 2009).

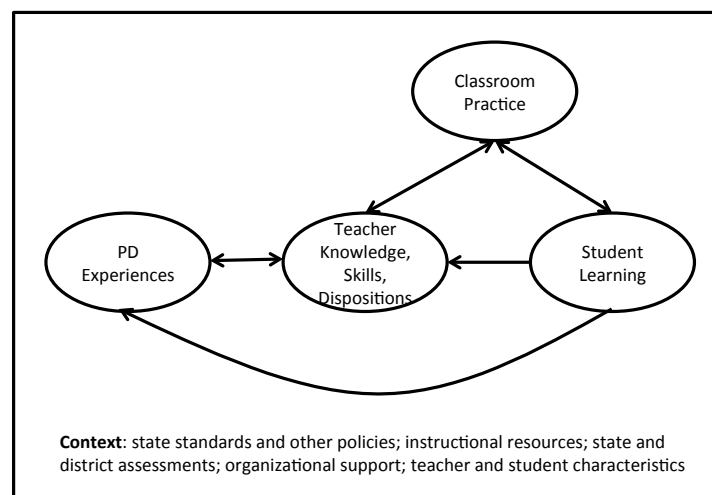


Figure 8. Theoretical framework for professional development.

Adapted from “Improving Impact Studies of Teachers’ Professional Development: Toward Better Conceptualizations and Measures,” by L. M. Desimone, 2009, *Educational Researcher*, 38, p. 185.

This review included examination of 25 studies that investigated different aspects of professional development for standards-based reform and its impact on teacher knowledge, classroom practice, and student learning. This discussion begins with an

overview of findings regarding professional development design and concludes with a commentary on the evaluation structure found in this group of studies. Note that because the research process on the impact of the CCSSM is yet in its infancy, the studies reviewed for this section examined the impact of previous reform efforts.

### **Professional Development Design**

As discussed previously, several core features have been identified as critical to successful professional development implementation, including content focus, activity-based learning opportunities, coherence, duration, and collective participation (Desimone, 2009). Of the 25 studies included in this analysis, only 11 included information regarding specific features of the teacher-learning opportunities. Table 1 indicates the number of studies that featured these core features.

Table 1  
*Core Features Represented in Selected Impact Studies (out of 11)*

Core feature	Number of studies
Content focus	10
Activity-based learning opportunities	6
Coherence	8
Duration	8
Collective participation	11

Of the studies that were examined, several focused on the core features of professional development that impact teacher knowledge (Borko, Jacobs, Eiteljorg, & Pittman, 2006; Cohen & Hill, 2000; Ferrini-Mundy et al., 2007; Heck et al., 2008). All five of these core features found prominence in the examined studies. Large-scale studies, which focused on approximately 50 or more professional development programs, indicate that the program designs incorporate all five of these design features (Desimone et al.,

2002; Heck et al., 2008). In addition, all five core features found different levels of prominence in the treatment design for specific studies.

**Content Focus.** Because most of the studies included in this investigation centered on mathematics-standards implementation, either in isolation or in conjunction with other studies, content focus can be inferred for all of them. Several articles specifically mentioned the mathematics content being emphasized, such as fractions (Saxe, Gearhart, and Nasir, 2001), geometric principles (Ferrini-Mundy et al., 2007), and reasoning and communication (Hill & Ball, 2004). The use of the term *content* in this context includes focus on both the mathematics content standards (e.g., number sense, geometry, measurement) and on the mathematical practices (e.g., problems solving, communication, representations; Borko, 2004; Ferrini-Mundy et al., 2007; Hill & Ball, 2004; Spillane, 2004).

**Activity-based learning opportunities.** Although most reports mentioned the use of interactive learning opportunities, several specifically describe the activities. In one study, teachers video-taped lessons implementing the Problem Solving Cycle. Videos were shared with the group followed by reflection and discussion (Borko et al., 2006). Another study focused on a multisite professional development institute. This study investigated the use of carefully designed tasks intended to increase teachers' content knowledge while focusing on student understanding within the context of the curriculum. These tasks included solving problems while simulating different grade-level responses, developing a multigrade continuum for geometric-concept instruction, and designing student activities (Ferrini-Mundy et al., 2007).

**Coherence.** Alignment between standards, instructional materials, and assessments is critical to moving standards-based teaching forward (Confrey, 2007; Ferrini-Mundy & Floden, 2007; Martone & Sireci, 2009; Porter, Smithson, Blank, & Zeidner, 2007; Schoenfeld, 2002). Collectively, these reports recognized that mathematics professional development increases its impact when it includes three features: alignment to standards (Hill, 2007b); connection to standards-based curriculum (R. Reys, Reys, Lapan, Holliday, & Wasman, 2003); and alignment to reform-curriculum materials and assessment (Cohen & Hill, 2000). The literature also states that districts should increase coherence by minimizing the concurrent implementation of multiple initiatives. One study in this set specifically examined three schools where mathematics reform was interrupted to introduce a new ESL program. The findings demonstrated that even in the midst of policy shift, mathematics teacher learning opportunities were sustained in one school due to two school-level strategies: a common, articulated vision for mathematics instruction and a large number of mathematics-focused teachers in the school (Kaufman & Stein, 2010). By attending to and integrating the efforts of multiple initiatives, leadership may be able to assist teachers in cohesive, coherent implementation if structured well.

**Duration.** To increase the likelihood long-term change, professional development must include 30–100 hours over 6 to 12 months (Darling-Hammond et al., 2009; Yoon et al., 2007). Several of the studies mentioned that the design included duration in these ranges. One in particular used a new measure to detect changes in teacher knowledge. In addition to indicating positive changes in MKT during the program’s extended summer workshop, the analysis also suggested that program length made a difference for the

MKT gain scores, as does workshop focus on mathematical analysis, reasoning, and communicating in predicting teacher learning (Hill & Ball, 2004).

**Collective participation.** The final core feature emphasizes the value of deliberate interaction between participants as they grapple with new content, ideas, and strategies. This characteristic was prevalent throughout this set of studies (Borko et al., 2006; Cohen & Hill, 2000; Ferrini-Mundy et al., 2007; Heck et al., 2008). One study in particular examined the relationship between teacher collaboration regarding standards-based reform and student achievement (Goddard, Goddard, & Tschannen-Moran, 2007). The results indicated that higher student achievement was associated with schools characterized by high levels of collaboration. The authors suggested that this evidence supports promoting collaboration regarding curriculum, assessment, and professional development decisions. Further study is warranted to determine the types of collaboration most closely associated with higher levels of student learning.

### **Impact on Teacher Knowledge**

**Mathematical knowledge for teaching.** Acknowledging that teachers' self-reports of changes in knowledge and implementation of standards-based strategies often fail to correspond with observation results (Spillane, 2004), well-designed professional development studies increase robustness by including measures and methods that provide direct evidence of said learning (Desimone, 2009; Loucks-Horsley et al., 2010).

Measures such as the LMT scales provide data regarding changes in teacher knowledge beyond mere conceptions (Hill & Ball, 2004). A combination of observations and interviews provide empirical evidence of the impact of professional development programs on teacher learning (Spillane, 2004). Such tools may also provide feedback



regarding specific elements of professional development design, such as the number of hours needed to make an impact as well as specific content focus (Hill & Ball, 2004).

However, an examination of teachers' perceived knowledge shifts after profound experiences may also provide insight into professional development design and its impact on notions of self-efficacy and intended implementation. Questionnaires, interviews, and self-reflections can provide evidence of increases of teachers' understanding of how students learn (Ferrini-Mundy et al., 2007). In addition, techniques such as discourse analysis may reveal a shift over time in the level of participants' engagement in reflective conversations focused on the content and pedagogy of standards-based mathematics instruction (Borko et al., 2006).

**Teacher conceptions and needs.** Teacher conceptions and beliefs make a difference in the implementation of standards-based mathematics teaching (Ferrini-Mundy et al., 2007; Handal & Herrington, 2003; Spillane, 2004). Often, mathematics professional development results fall short of the goals because the programs neglect educators' conceptions, needs, background knowledge, and beliefs (Borko, 2004; Chval, 2008; Desimone, 2009; Loucks-Horsley et al., 2010). A survey, administered to a stratified random sample of 1000 mathematics and science teachers, examined teachers' conceptions of the quality of professional development they received as well as the degree to which their needs were met (Chval et al., 2008). These results suggested that mathematics teachers attend a minimal number of professional development opportunities for a variety of reasons, including a mismatch between their professional growth needs and their actual experiences in the past.

### **Impact on Classroom Practice**

Although several studies indicated positive changes in classroom practice related to standards-based professional development, many of these studies relied on self-reported data rather than measures of teacher knowledge (Ferrini-Mundy et al., 2007; Heck et al., 2008; Wallace, 2009). In essence, these studies collected teacher conceptions rather than actual classroom practice data. This practice often leads to incorrect conclusions regarding implementation of new strategies. First, some researchers have found that implementation of learned skills is more complicated than originally anticipated (Cohen & Hill, 2000). Second, teacher conceptions of change often does not conflict with observation data. One study surveyed many teachers to obtain their conceptions regarding implementation of standards-based principles (Spillane, 2004). After collecting the data, 25 teachers who perceived themselves as highly implementing standards-based principles were selected to participate in follow-up observations and interviews. The researchers found that only four of the 25 selected teachers were using reform-minded strategies, such as the use of alternative solution strategies and purposeful small-group problem solving, with fidelity. This implies that using only teacher-reported data regarding implementation may not provide reliable research data.

### **Impact on Student Learning**

As mentioned previously, individual impact studies on reform-based teaching reveal increased student learning and achievement on small scales, but large-scale conclusions are difficult to construct, in part due to the variance in state standards and assessments (Ferrini-Mundy et al., 2007). To make matters worse, the NCLB has

obstructed the standards movement's progress on many levels (Confrey, 2007; Ferrini-Mundy & Floden, 2007; Ravitch, 2010). Confrey (2007) stated,

the NCLB Act has the theoretical appearance of a standards-based policy, however, because the testing models are simply imported from the accountability movement, and appended only loosely to the standards, the opportunity to stimulate coherence has been lost (p. 46).

Furthermore, because the NCLB promoted centralized accountability while placing the responsibility for standards writing in the hands of individual states, the quality and rigor of the standards themselves vary greatly from one state to the next (Klein et al., 2005). In addition, NCLB also dictates that each state create its own assessment to measure standards, proving yet another inconsistency in student-learning data. Taking into account the discrepancies in research, state standards content, and state-level assessments, overall conclusions of the impact of standards on student learning are difficult to make (Confrey, 2007; Ferrini-Mundy & Floden, 2007; Klein et al., 2005; B. J. Reys et al., 2006).

As Ferrini-Mundy and Floden (2007) pointed out, little can be concluded about standards-based teaching and learning as they relate to policy. However, many small-scale studies have shown promise in the impact of standards-based teaching and learning. The following are but a few that support the use of standards-based curricula and professional development, showing an impact on student achievement.

- R. Reys et al. (2003) found that eighth-graders using a standards-based curriculum in three school districts scored higher on the Missouri Assessment Program than comparison groups similar in past mathematics achievement and income levels in other districts.

- Saxe et al (2001) conducted a study focused on the development of fraction concepts. Teachers in the treatment group receiving specific training in MKT and standards-based methods and the control group teachers simply met to discuss such general practices as homework and manipulatives. When student data were examined, the students in treatment-group classrooms scored over a standard deviation higher than those in the control-group classrooms.
- Carpenter et al., (1989) conducted a study in which teachers were trained using specific problem solving strategies and methods related to cognitively guided instruction. In student assessments, the students in the treatment-group classes scored significantly higher than control group students.

Beyond tying teacher learning to student achievement, these studies also support the claims that professional development needs to be better aligned with district standards, curriculum materials, and assessments (Hill, 2007b).

## **Evaluation**

In an effort to validate the many claims that research in the professional development space often neglects program outputs, including growth in teacher knowledge, classroom implementation, and student learning, and because Guskey's (2000) five levels of evaluation play a central role in this dissertation, the impact studies were also reviewed for evidence of including one or more of Guskey's levels. The studies selected for this review strongly support the claims that observations, interviews, and surveys comprise the majority of measurement tools used within the professional development research (Desimone, 2009; Guskey, 2000). They also support Guskey's (2000) (and others') claims that professional development research rarely focuses on

student achievement indicators. Upon analysis of the 25 impact studies, 22 of those studies focused on instrumentation, and the instrumentation used included five areas (Table 2).

Table 2  
*Instrumentation Used in Selected Impact Studies (out of 22)*

Instrument	Number of studies
Surveys	15
Interviews	14
Observations	11
Measures for student learning	5
Measures for teacher knowledge	2

Furthermore, the extensive use of observations, interviews, and surveys also reveals a lack of emphasis on Level 2 (participant learning), Level 4 (participants' use of knowledge), and Level 5 (student learning). Of the 25 studies included, 22 of them indicated use of one or more levels of evaluation; of those, only two indicated examination of all three of the output variables (Cohen & Hill, 2000; Goddard et al., 2007). Table 3 reflects the levels of evaluation included in this assessment.

Table 3  
*Levels of Evaluation Represented in Selected Impact Studies (Out of 22)*

Level of evaluation	Number of studies
1. Participant reactions	13
2. Participant learning	5
3. Organizational support	13
4. Participants' use of knowledge	7
5. Student learning	5

These numbers are somewhat generous in that any effort to monitor growth in the program outputs were counted, even data collected from participant self-reports. For example, five of the studies reported on participant learning, but three of those five used

self-reported data (Borko et al., 2006; Heck et al., 2008; Spillane, 2004) rather than observed data such as from written assessments (Abel et al., 2007; Hill & Ball, 2004).

### **Summary**

After decades of standards-based teaching and learning, very few overall conclusions can be drawn based on the research gathered at this time. However, as discussed in the previous pages, several principles emerge as one reviews the literature:

- Effective professional development includes elements of content focus, activity-based learning opportunities, coherence, duration, and collective impact (Desimone, 2009; Desimone et al., 2002; Loucks-Horsley et al., 2010).
- Differences in student learning reflect the kinds of learning opportunities teachers receive in regards to increasing their knowledge and implementation skills for standards-based instructional policy (Cohen & Hill, 2000).
- Leadership matters in the translation and support of standards implementation (Cohen & Hill, 2000; Confrey, 2007; Darling-Hammond et al., 2009; Hill, 2001; Spillane, 2004).
- Teacher conceptions and beliefs make a difference in the implementation of standards-based mathematics teaching (Chval et al., 2008; Ferrini-Mundy et al., 2007; Handal & Herrington, 2003; Spillane, 2004).
- Written curricula that support standards-based teaching should be accompanied by professional development (Cohen & Hill, 2000; Ferrini-Mundy & Floden, 2007).
- The CCSSM will live up to its potential only if teachers receive the training and support they need to implement both its content and practices at the

classroom level (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012).

Unfortunately, current evidence remains inconclusive about the systemic impact of professional development on standards-based teaching and learning. However, small-scale successes continue to reveal that student learning increases when teachers truly embrace the standards, emphasizing conceptual understanding and focused discourse and helping students make meaning of the mathematics rather than simply executing procedures.

So, what comprises exceptional standards-based mathematics professional development? First, professional development requires clear communication of the standards through a variety of means, including

- efforts to accurately understand and implement the meaning and intent of the standards, in this case, the CCSSM;
- documents, tools, and curriculum materials selected or created by well-informed district leaders that accurately translate state-level standards; and
- organizational structures including selection of professional development models that include such features as collective participation and strong networking systems.

Second, exceptional standards-based mathematics professional development includes specific professional development features, including the five core features (content focus, active learning, coherence, duration, and collective participation), and attends to teacher learning needs, prior knowledge, existing conceptions, and developing beliefs. Third, outstanding professional development includes examination of all levels

and impacts of the professional development programs, emphasizing effects on teacher knowledge, instructional practice, and student achievement. Fourth, organizational structures and leadership facilitate implementation of standards-based practices aligned to policymakers' intentions.

Teachers need multiple opportunities to develop their understanding of state-level mathematics standards beyond traditional training models. These opportunities include organizational support systems with leaders knowledgeable in standards-based mathematics, interactions with standards-based written materials, professional conversations and collaboration with peers, and sustained, ongoing learning experiences. More varied the opportunities teachers receive to learn and relearn various aspects of MKT will increase their chances of changing their practice to support the CCSSM, resulting in an enacted and attained curriculum that benefits students.



## CHAPTER 3

### RESEARCH DESIGN AND METHODS

This study examined the impact of a professional development treatment on teacher knowledge of the CCSSM and the impact of increased teacher knowledge on classroom instruction and student learning. The professional development treatment included the five core features of professional development addressed by Desimone (2009): content focus, activity-based learning, coherence, duration, and collective participation. The impact of this treatment was examined by comparing the experimental group to a control group as well as by replicating the treatment with a second group. (In the spring semester, the original control group attended the same program received by the treatment group.)

The measures chosen for this study include four levels of Guskey's (2000) professional development hierarchy: participants' reactions, participants' learning, participants' use of new knowledge and skills, and student-learning outcomes. Although the fifth level, organizational support and change, was observed as part of the professional development design, it was beyond the scope of this study, which examined the impact of the treatment on teachers' knowledge, instructional practice, and student learning.

#### **Research Questions**

To examine the impact of the treatment, three questions were addressed:

1. What is the relationship between professional development for the CCSSM and teacher knowledge, skills, and dispositions?

2. What is the relationship between professional development for the CCSSM and classroom practice?
3. What is the relationship between professional development for the CCSSM and student learning?

### **Research Design**

This mixed-methods study included both quasiexperimental and qualitative components. Thirty-eight second-grade teachers were randomly assigned to either the experimental or control group prior to the beginning of the study. The design included a pre–post–post model (Shadish, Cook, & Campbell, 2002). At the beginning of the fall semester, a pretest was administered to the participants in both groups prior to the treatment, and a posttest was administered at the end of the initial treatment, which coincided with the end of the fall semester. Subsequently, during the spring semester, the teachers in the control group became the participants in a replication of the initial treatment, hereafter referred to as the *follow-up*. A final posttest was administered to all participants upon the completion of the follow-up at the end of the spring semester.

The quantitative components, addressing Questions 1 and 3, relied on a design that consisted of the untreated control group and an experimental sample, with participants randomly assigned, during the fall semester (Shadish et al., 2002). This design was used to examine whether differences existed between the experimental group (professional development participants) and the control group (nontreatment participants) during the initial treatment and then to examine whether similarities in growth scales existed between the groups after the follow-up.

The qualitative component, addressing Question 2, included the use of observation and interview protocols administered to a subset of four experimental and four control teachers in matched pairs during the initial treatment. These observations and interviews were designed to examine differences in the way experimental and control teachers approached the teaching of specific grade-level mathematics standards. Four experimental teachers and their matches from the control group were selected based on the results of the pretests. More specifically, the matched pairs were selected based on treatment and control teachers who taught students with similar demographics (e.g., who taught at the same school) and received similar LMT scores.

In addition, to further examine all three research questions, qualitative methods were used to analyze the participant reflections and field notes collected throughout the treatment. Table 4 outlines the alignment between the research questions, instrumentation, methods, and analyses used in this study.

### **Participants and Context**

The 38 participants taught in a mixed urban/suburban school district in the Phoenix Metropolitan Area in Arizona. All 12 of the district's schools participated. Of the 12 schools, seven had 70% or more of their student population qualifying for free or reduced-price lunch. Of the 38 participants, nine were Hispanic and 28 were Caucasian; 35 were female and three were male. Five teachers were in the first 2 years of their careers, and those same five were in their first 2 years of teaching second grade. See Appendix B for the Institutional Review Board approval for this study.

Table 4  
Alignment Table

	Participants' MKT	Participants' knowledge of the CCSSM	Classroom observations	Participant interviews	Student assessments
Rationale	The professional development included in this study was designed to directly impact teacher knowledge and understanding of the CCSSM and the skills to implement the CCSSM effectively as compared to teachers who did not receive the professional development.		The professional development included in this study was designed to indirectly impact teacher effectiveness in implementing the CCSSM in their classrooms as compared to teachers who did not receive the professional development.		The professional development included in this study was designed to indirectly impact student achievement in the classes of participating teachers as compared to those who did not receive the professional development.
Research question	What is the relationship between professional development for the CCSSM and teacher knowledge, skills, and dispositions?		What is the relationship between professional development for the CCSSM and classroom practice?		What is the relationship between professional development for the CCSSM and student learning?
Methods/ instrumentation	LMT	Online sorting activity	RTOP	Stimulated-recall, semistructured interview	<i>Galileo</i> student assessment
Analysis	Mean scores were compared to determine differences between the experimental and control groups.		Data were coded and analyzed to detect differences between treatment and comparison teachers during Treatment 1.		Mean scores for the classrooms in each group were compared to determine differences.
Analytic methods	Repeated measures ANOVA; independent <i>t</i> -tests		ANOVA	Content Analysis (Miles & Huberman, 1994)	Repeated measures ANOVA
Additional data	Participant reflections were completed and collected during the final session of the initial treatment and the follow-up. The reflections were analyzed using the constant comparison method (Dye et al., 2000).  Field notes from the treatment sessions were transcribed, coded, and analyzed to provide qualitative support for changes in the teacher knowledge, instruction, and student learning during each of the treatments. The field notes were analyzed using the sequential analysis method from Miles and Huberman (1994).				

Notes: RTOP = Reformed Teaching Observation Protocol.

The 38 teachers were randomly assigned to either the experimental or control group prior at the beginning of the study. The unit of study was teacher, as opposed to school, so teachers in the treatment group had same-school colleagues who were assigned to the comparison group. Because of this, comparison teachers may have been impacted

by the treatment through their participating colleagues, thereby biasing the results. However, requests to withhold the course content from comparison colleagues until the end of the initial treatment were frequently repeated, and most participants claimed that no sharing took place until the spring semester.

### **Treatment Design**

The treatment in this study included approximately 50 hours of professional learning opportunities based on the CCSSM over the course of 6 months (3 months per treatment). These learning opportunities included six 7-hour workshop sessions spaced 2 to 3 weeks apart, ongoing online communication, and between-session assignments such as examining student work, reading related literature, and implementing specific teaching strategies. All professional learning opportunities were designed and facilitated by the researcher. The components centered on helping teachers understand the content and the intentions underlying the CCSSM by examining the documents themselves and participating in classroom activities that served to exemplify the objectives of the CCSSM. A repeated emphasis was placed on the need to connect the content standards with the mathematical practices to achieve optimum results.

### **Content**

The workshop sessions provided teachers with the opportunity to focus on the CCSSM content standards at their specific grade level with frequent reference to what lies beyond the horizon in other grade levels (Ball et al., 2002; Desimone, 2009). Each session focused one or two domains from the second-grade CCSSM, concentrating on the content of each standard within that domain as well as what was “missing.” For example, prior to the treatment, the teachers in this study had traditionally focused on teaching

standard algorithms for addition and subtraction for two- and three-digit numbers. However, in examining the CCSSM, they discovered that they are to teach addition and subtraction using strategies based on place value, properties of operations, and relationships between addition and subtraction. With the discovery that the CCSSM does not introduce standard algorithms for addition and subtraction until fourth grade, the participants better understood their need to learn new ways for teaching and learning these concepts.

In addition, significant time was devoted to examining how to embed the SMP into student learning opportunities. Most of the participants did not have a working knowledge of the NCTM process standards (NCTM, 1989, 2000); therefore, they had little background on teaching mathematics using such strategies as inquiry methods, student-led conversations, or hands-on learning. Beginning in the second session, the SMP were emphasized during each meeting, with an emphasis on strategies the teachers were implementing in their classrooms to facilitate student engagement with these practices. Descriptions of the SMP can be found in Appendix A. Table 5 provides a brief overview of the topics covered in each session. A detailed table of workshop sessions and activities appears in Appendix C.

### **Interactions**

Equivalent amounts of time were designated for participating in interactive learning sessions led by the facilitator and for engaging in small-group interactions (two to four teachers per group) for concentrated curriculum planning and preparation. During the planning time, participants examined written materials, role played, created lesson

plans, set goals for their own instruction, and examined student work from the previous session.

Table 5  
*Professional Learning Opportunities—Workshop Session Topics*

Session	Session content
1	Overview of CCSSM Content Standards (second-grade emphasis) Number and Operations in Base 10—Part 1 (place value)
2	Overview of CCSSM Standards for Mathematical Practice Number and Operations in Base 10—Part 2 (place value and operations)
3	Number and Operations in Base 10—Part 3 (place value and operations, cont.) Operations and Algebraic Thinking—Part 1 (math facts)
4	Operations and Algebraic Thinking—Part 2 (problem types) Measurement and Data—Part 1 (money and time)
5	Operations and Algebraic Thinking—Part 3 (foundations for multiplication) Measurement and Data—Part 2 (data analysis, measures of length)
6	Geometry Fractions

Generally speaking, each session included a variety of activities intended to focus the participants on their grade-level standards, unveiling the contents of the standards in each domain, exploring the content embedded throughout, and discussing innovative ways for introducing the content to students. Following is an overview of the primary activities that took place during the course.

**Content standards introduction.** This 2-hour introductory activity took place only on the first day. The participants were asked to sort mathematics topics into a Venn diagram to indicate which topics they believe appear in the second-grade CCSSM, which appeared in other CCSSM grade levels, and which did not appear in the CCSSM. Most of these topics were taken from the former state-level mathematics standards document. Following this initial sort, the participants worked in groups of four to organize random lists of the CCSSM second-grade content standards into domains. After completing this sort and checking it with the CCSSM document, participants moved back to their original

groups to make changes to the topics they originally sorted on the Venn diagram. These interactions set the foundation for the participants to rethink what they believed they are supposed to teach and provided a purpose for reading all of their grade-level standards.

**Warm-up task.** At the beginning of Sessions 2 through 6, the participants interacted in a problem solving task. The participants chose tasks requiring problem-solving strategies—such as drawing pictures, making tables, and modeling with mathematics. They were then asked to anticipate possible student solution strategies as they solved the tasks for themselves. This allowed the teachers to consider alternative problem-solving strategies and to share their thoughts with colleagues. These warm-up tasks then became the tasks used for the student-work-analysis segment for the following session.

**Student-work analysis.** Following each session, participants were asked to do specific tasks with their students to gather data about how their students engaged with both the content and the SMP. Participants selected samples from the student work and brought them to class to discuss student progress. These discussions focused on both what did and did not work during the implementation. A specific protocol was used, asking the participants to (a) describe their own student work in writing, (b) share their descriptions with the table-top group and then make generalizations for the group, and (c) make recommendations for changes in classroom instruction based on the analysis. This was followed by a whole-group conversation led by the facilitator.

**SMP review.** A deep reading of the SMP was completed during the morning of the second session. During each subsequent session, 20 to 30 minutes were spent



reviewing the SMP and how they were implemented during the weeks between sessions. Different activities were designed for each session.

**Content standards talk.** At the beginning of each content session, the participants reread the standards within the domain to be discussed. I then led a discussion about the meaning of each standard, providing insights based on the literature focused on that specific content. Participants were invited to ask questions and to reflect on how their notions of those topics needed to change as a result of the reading, conversation, and learning that took place.

**Workshop.** Each session typically included one or two workshops focused on the domain being discussed. These workshops included interactions such as discussions, readings, research literature reviews, analyses of hands-on activities, and video viewings, all aimed at furthering the participants' knowledge of the content standards at hand and helping them anticipate ways for embedding these ideas into instruction. Emphasis was also placed on embedding the SMP into the teaching and learning of those content standards.

**Book talk.** For Sessions 2 through 6, participants were asked to read portions from *Teaching Student-Centered Mathematics* (Van de Walle & Lovin, 2005) prior to class. The selected chapters focused on the topics to be discussed that day. I began each book talk session with a brief overview, followed by table-top discussions regarding both the content and the sample activities provided in the book.

**Work session.** Participants spent 30 to 40 minutes during each session discussing and planning their use of what they had learned that day. They used various resources such as the Van de Walle and Lovin (2005) book, workshop packets, class tasks, district

resources, curriculum maps, and pacing guides to assist in the process. Emphasis was placed on embedding their new learning into the existing support structures within their schools and districts. Particular attention was paid to the teacher-evaluation instrument, the district pacing guide, and the student benchmark assessments.

### **Additional Treatment Features**

**Mathematical knowledge for teaching.** The treatment included a focus on the contents of the CCSSM, concentrating on both increasing teacher knowledge of the concepts to be covered at their specific grade level and deepening their understanding of the MKT inherent in those standards. For example, CCSSM cluster 2.MD requires that second-grade students “relate addition and subtraction to length” (National Governors Association, 2010, p. 20). They are more specifically required to “use addition and subtraction within 100 to solve word problems involving lengths” as well as to “represent whole numbers as lengths from 0 on a number line diagram.” As the teachers contemplated these standards, several commented on how they needed to learn how to use number lines for modeling arithmetic as well as to reinforce place value and number sense. As the participants were challenged to think beyond their own traditional ideas for teaching arithmetic strategies, their MKT increased in the process.

**Dialogue across schools.** This treatment was designed to develop professional communities by using grouping structures with different purposes, always with the intention of maximizing their interactions. For example, several participants commented on the value of dialoguing with teachers from other schools when planning lessons, analyzing tasks, and examining student work. Although most participants tended to sit with same-school colleagues, the learning opportunities designed within each session

provided opportunity for teachers to discuss curriculum and other issues with those from different schools. This frequently resulted in spontaneous sharing of ideas, evidenced by requests that I make copies of materials brought to share with participants' colleagues from other schools.

**Organizational support.** The treatment in this study emphasized the use of district-designed mathematics resources so that teachers were able to focus on the mathematics they taught as outlined in the CCSSM rather than being distracted by the many sources they use. For example, teachers were asked to bring their district-adopted textbooks, supplemental planning materials, and district pacing guides to the workshop sessions. They used these resources, in conjunction with the original CCSSM document, to put together coherent plans based on their grade-level standards.

In addition, to enhance coherence, I met with the district curriculum director and the district professional development coordinator approximately twice per month to specifically discuss issues of coherence regarding the CCSSM and assessment, district curriculum policies, behavior management, principal observations, and other issues relevant to maintaining coherence for teaching and learning the CCSSM.

### **Data Collection, Instrumentation, and Analytic Tools**

The purpose of this study included efforts to discern the effects of a professional learning structure focused on the CCSSM on participants' MKT, classroom instruction, and student learning. Five instruments were used to detect these effects: two measures of teacher knowledge, a measure of student knowledge, an observation protocol, and a stimulated-recall interview protocol. In addition, field notes and written participant

reflections were analyzed using qualitative methods. Each instrument is described below along with the corresponding analysis procedure(s).

### **Question 1: Indicators of Change in MKT**

This study used two data sources reflecting changes in the participants' MKT: the LMT scales, and an online sorting task. The LMT and online sorting task, both quantitative measures, provided the study with data intended to detect differences in MKT and knowledge of the common core standards in the experimental and control groups. In addition, participant reflections and field notes were used to provide qualitative evidence of changes in teacher knowledge; these will be discussed at the end of this section because they provided evidence for all three research questions. Each instrument or method is described below.

**Learning mathematics for teaching scales.** The LMT Project investigates the mathematical knowledge needed for teaching and how professional learning and experience impact this knowledge. As part of ongoing work by Ball and associates, the LMT Project designed assessments intended to measure the impact of professional development on teachers' MKT (Hill, 2007a). The items on these scales focus on common mathematics-instruction tasks and were designed to tap into teachers' common and specialized knowledge of mathematics content taught in grades K–6 (Hill & Ball, 2004). These items were drawn from research literature (e.g., Ball, 1993a, 1993b; Carpenter, Hiebert, & Moser, 1981; Lamon, 1999; Lampert, 2001; Ma, 1999) as well as the writers' own experiences in elementary classrooms.

The LMT scales were designed to compare MKT for groups of teachers, not to compare individual teachers. Typically, a reliability of .7 is adequate for finding

moderate effects in groups of 60 or more, but a reliability .9 is necessary to make claims about the differences between individuals (Hill, 2007a). The scales used for this study have one-parameter reliabilities of .79 (form A04) and .74 (form B04), allowing them to detect effects between groups, but not individuals. Note that errors in measurement may occur with fewer than 60 participants, which may be the case in this study ( $n = 38$ ).

The two forms used for this study were equated using common-person equating. All items were placed on the NCOP-EQ form and piloted with Quality Educational Data's teachers and were equated using one-parameter Item Response Theory (IRT) results. Tables for converting raw scores to IRT scores were created during the equalizing process. For the current study, all LMT scores were reported as IRT scores, which allowed for controls between the forms (Hill, 2007c).

LMT scales were used in the current study for two reasons. First, the scales were used to detect a difference in change between the treatment and control groups during the first half of the study ( $n = 18$  and  $n = 14$ , respectively). Second, the scales were used to document the average amount of gain in treatment participants' MKT, regardless of the experimental group in which they participated ( $n = 38$ ).

For this study, the 2004 version of the LMT scales was used to gauge teacher knowledge of mathematics. Forms A04 and B04 of the Number Concepts and Operations—Content Knowledge were selected for two reasons: (a) they were available as online assessments using the Teacher Knowledge Assessment System, and (b) although the 2002 forms were also available online, the 2004 version was built upon items from the 2002 forms, with items added to improve the measurement properties (Hill, 2007a). Using the Teacher Knowledge Assessment System, participants in this

study were randomly assigned one form for the pretest, and then given the other form for the first posttest and the first, again, for the second posttest. This allowed for pre–post controls without significant concern about test-retest effects.

To detect an effect of the CCSSM professional learning treatment on teacher knowledge, the LMT online assessment was administered three times: before Treatment 1, between treatments, and after the replication treatment. The LMT scores were used to determine the amount of change from pre- to posttest results during the fall semester as well as growth scores for the follow-up group during the spring semester. Although the two forms of the LMT scale had been equalized by the designers, as previously mentioned, an administration error occurred for which account must be made. The online version of the LMT randomly assigns one form of the test to participants for the pretest and then administers the opposite form for the posttest. However, when administering the posttest at the conclusion of the first treatment, I provided the incorrect code to the first experimental group. This resulted in only half of this group receiving the alternate form, whereas the other half received the same form taken in the pretest. A statistical analysis of the two LMT forms suggested that in this case, the forms were not equivalent, which may have skewed the results and analytics that follow.

A repeated measures ANOVA was used to analyze this data set, as described in Chapter 4. Note that one teacher in the experimental group was not included in the LMT analysis because she went on maternity leave the morning of the last treatment day and was unavailable to take the posttest. In addition, two teachers in the experimental group failed to take the May posttest, and six teachers in the control group failed to participate in the October pretest, thereby eliminating them from the LMT analysis in Chapter 4.

**Online sorting task.** Sorting tasks were originally designed by psychologists to detect ways in which people organize their knowledge (Wood & Wood, 2008). Relatively small sample sizes can yield significant results, with as few as 25–30 participants achieving results similar to hundreds (Tullis & Wood, 2004). Therefore, this tool was appropriate for a study with 38 participants. Following Tullis and Wood (2004), the items were randomized to prevent biasing towards a predefined category.

For the purposes of this study, an online sorting task was designed using a commercial website, WebSort (<http://www.websort.net>). Online sorting tasks have been found to produce similar results to paper sorting tasks (Bussolon, Russi, & Del Missier, 2006). The sorting task for this study included a list of 40 mathematics topics, 30 of which are covered in the CCSSM for the designated grade level, and 10 of which are not. The participants were asked to sort each topic into one of three bins: (a) Specifically addressed or inferred in the second-grade common core, (b) Not specifically addressed or inferred in the second-grade common core, or (c) “I’m not sure.” Participants were asked to sort the topics quickly, using no outside resources. They were also asked to place topics in the “I’m not sure” bucket when they were uncertain rather than to guessing. A screen shot of the sorting task and instructions appears in Appendix A.

Because the sorting task was designed as an instrument specifically for this study, issues of reliability and validity were addressed. To address issues of validity, outside experts on the mathematics standards, including authors of those standards and state-department mathematics leaders, were asked to complete the sorting task, and they had a 94% combined consistency rate. To address issues of reliability, 10 of the 40 mathematics topics were repeated at random in the sort to see if the participants

consistently placed the topics in the same categories. In addition, the topics appeared in random order on the computer screen each time the task was administered.

This sorting task was completed three times by the participants in each group: before the initial treatment (October), after the initial treatment (January/February), and after the follow-up treatment (May). Participants directly involved in each treatment, both the initial experimental group and the replication group, completed the sorting task in a controlled environment for both the pre- and posttest situations. Teachers assigned to the control group during the initial treatment completed the pretest on their own but completed the posttest in a controlled environment.

The sorting task scores were used to determine the amount of change from pre- to posttest results during the fall semester as well as growth scores for the follow-up group during the spring semester. Independent *t*-tests were used to analyze this data set, as described in Chapter 4. Once the pre–post scores were collected for the online sorting task, I organized each participant’s scores into a 3x3 matrix to determine the positive and negative growth scores (see Figure 9). The matrix was set up with the three possible pretest score categories (hit, don’t know, and miss) along the *x*-axis and the three possible posttest score categories (hit, don’t know, and miss) along the *y*-axis. Counts for each section in the matrix were determined by counting the number of changes or nonchanges for each item in the assessment. For example, if a participant sorted an item incorrectly in the pretest and correctly in the posttest, it was counted as “+” (“miss–hit”) and counted as positive growth.

Positive growth was determined by counting all items that went from miss to hit or don’t know to hit. Negative growth was determined by counting all items that went



from hit to miss or don't know to miss. Items that did not indicate change (e.g., from hit to hit, don't know to don't know, or miss to miss) were counted as no growth. Figure 10 illustrates how each (non)transition was counted.

		Pretest		
		Hit	Don't Know	Miss
Posttest	Hit	no growth	+ growth	+ growth
	Don't Know	- growth	no growth	+ growth
	Miss	- growth	- growth	no growth

Figure 9. Sorting task matrix used to determine positive and negative growth scores.

Note that as with the LMT results, one teacher in the experimental group was not included in the analysis of the online sorting task because she went on maternity leave the morning of the last treatment day and was not available to take the posttest. In addition, two participants in the experimental group failed to take the May posttest, and six teachers in the control group failed to participate in the October pretest, thereby eliminating them from the online sorting task analysis in Chapter 4.

### Question 2: Indicators of Changes in Classroom Practice

This study used four data-collection methods to examine changes in teacher practice. The field notes and participant reflections described above were collected and analyzed to detect perceived changes in classroom practice for all participants. However, the only way to truly determine whether differences truly existed was to directly observe

classroom practice (Spillane, 2004). Therefore, four matched pairs of teachers were selected to participate in classroom observations and stimulated-recall interviews.

Each matched pair consisted of one teacher from the experimental group and one teacher from the control group, selected based on two primary criteria: teaching assignment at the same school and similar LMT scores. Once selected, an independent evaluator conducted three observation-interview sessions in the classrooms of each of the eight selected participants. Note that one of the matched pairs was only observed twice as the treatment teacher went on maternity leave the day prior to the final observation-interview.

Two instruments were used to identify differences in classroom practice between matched pairs of experimental and control teachers. The *Reformed Teaching Observation Protocol* (RTOP) was used to collect data during observations of classroom instruction. As a follow-up to each observation, a semistructured, stimulated-recall interview was conducted to identify differences in the ways matched-pair teachers identified their decision making during the course of the observed lesson. Descriptions of the observation and stimulated-recall interview protocols appear below.

**Observation protocol: Reformed teaching observation protocol.** The RTOP was used to identify the impact of the treatment on classroom teachers' practices as compared to control teachers. The RTOP provides a standardized means for observing mathematics and science teachers and detect the degree to which the instruction is aligned with reform-based principals. These reform-based principals align with the 1989 NCTM *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and the 2000 version, *Principles and Standards of School Mathematics* (NCTM, 2000),

one of the guiding documents for the CCSSM. The NCTM Standards documents emphasize the need to develop conceptual understanding in mathematics and the benefits of embedding five processes into mathematics instruction regularly: communication, connections, problem solving, reasoning, and representation. These foundation elements of the NCTM Standards documents were predecessors of the SMP described in the CCSSM (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). Because the RTOP relies heavily on the NCTM Standards' recommendations for reform mathematics teaching, and the NCTM Standards heavily influenced the CCSSM, the RTOP was selected for use in the current study.

The RTOP was designed by the Evaluation and Facilitation Group of the Arizona Collaborative for Excellence in Preparation of Teachers to measure “reformed” teaching. The designers cite several principles as defining elements for mathematics reform including constructivism (Piagetian theory, sociolinguistic theory, and current conceptions of constructivism such as that of Coburn) and the NCTM *Principles and Standards for School Mathematics* (Piburn & Sawada, 2000). The 25 items that appear on the instrument fall into five categories:

1. Lesson Design and Implementation
2. Content: Propositional Pedagogic Knowledge
3. Content: Procedural Pedagogic Knowledge
4. Classroom Culture: Communicative Interactions
5. Classroom Culture: Student–Teacher Relationships

The overall reliability for the instrument was very high ( $r^2 = .954$ ). Construct validity was also calculated for each subscale (the categories listed above), looking at

how well each functioned as a predictor of the RTOP total score. The reliabilities for each subscale are as follows: (a) .956, (b) .769, (c) .971, (d) .967, and (e) .941 (Piburn & Sawada, 2000). The face validity of RTOP was established with credibility of the sources consulted, including NCTM's *Principles and Standards for School Mathematics*. The evaluators also correlated RTOP with normalized gain scores on a pre–post mathematics test, with a correlation of .94 for conceptual understanding and .92 for number sense (Piburn & Sawada, 2000).

To address issues of reliability, an external evaluator conducted all 22 observations and interviews and did not know ahead of time which participants were in the experimental group and which were in the control group. Prior to beginning this process, interrater reliability was established between the evaluator and me to ensure consistency between the data collection and data analysis processes (Shadish, et al., 2002). The observer and I co-observed and coded three online lessons, and then compared their coding to ensure common scores occurred. A 94% accuracy rate was achieved in the final observation. The coding instrument is included in Appendix D.

Three observations occurred in each of the four treatment participants' classrooms and their matched control counterparts. These informants were selected based on same-school assignment and similar LMT scores. Each matched pair of teachers was asked to present a lesson on the same agreed-upon objective 1 week prior to the observation. These observations took place after the third, fifth, and sixth treatment dates during the fall semester. The intended outcome for the observations encompassed the collection of evidence to confirm or disconfirm that differences existed between the treatment teachers and their matched control counterparts.

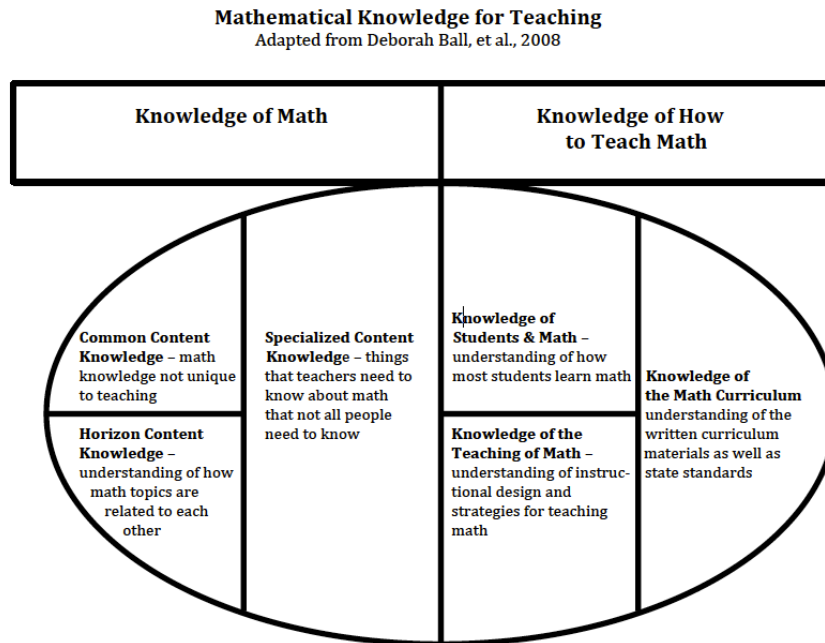
To analyze the RTOP data, an ANOVA was calculated using the mean RTOP score and then blocking on each matched pair to factor out the effects of similar school and LMT pretest scores. The results will be discussed in Chapter 4.

**Semistructured, stimulated-recall interview protocol.** Immediately following each classroom observation, the observer conducted a 5-to-10-minute stimulated-recall interview to further probe the teachers' conceptions of their classroom practices. Stimulated-recall interviews have been identified as useful tools to help informants recall their concurrent thinking during an event (Ericcson & Simon, 1993).

For this study, the interview was designed to probe the teachers' intentions and decision making regarding classroom practices during the observed lesson using a stimulated-recall format. Note that the interviewees received a copy of the interview questions and the MKT chart via email prior to each observation. In addition, the teachers in the experimental group used the MKT chart during their midcourse and final reflections. The interview protocol, in its entirety, appears in Appendix A.

Just prior to each observation, the observer or interviewer informed the participant, "After the observation, I'll be asking you to describe a point in the lesson where you made a significant decision regarding the math you were teaching." Once the observation was complete, the external evaluator questioned the teacher to further probe his or her thoughts and reflections regarding the observed classroom practices using the preestablished protocol. In each case, the interviewee selected the topic of reflection, though the observer was ready to pinpoint a moment for reflection, if necessary. The interview included three prompts:

1. Name a point in the lesson where you made a significant decision regarding the math you were teaching.
2. What were you thinking as you made that decision? (Follow-up if needed: What did you see the student(s) do that prompted your decision?)
3. Here is an example of the different kinds of knowledge teachers use when they're making decisions while teaching math. [Show chart—describe briefly as needed.] Which of these do you think had an impact on your decision? How did it have an impact? (See Figure 10.)



*Figure 10.* MKT chart used during stimulated-recall interviews. From “Content knowledge for teaching: What makes it special?” by D. L. Ball, M. H. Thames, and G. Phelps, 2008, *Journal of Teacher Education*, 59, p. 403.

Each interview was audiorecorded and transcribed. Content analysis was used to organize elements of the interview transcript into categories, identifying the prevalence of common concerns and ideas (Miles & Huberman, 1994). During the analysis, I sought further insight into the teachers’ translation of the CCSSM for their classroom practices,

attempting to identify differences between the experimental and control teachers' responses. Results of this analysis are discussed in Chapter 4.

The interview data were analyzed in five stages. First, I entered the data into spreadsheets, one sheet for each participant. Interviewer prompts were separated from respondent reflections, and a simple coding system was used to record which reflections matched up with each question (1, 2, or 3). The simple coding system was based on a list of MKT descriptors (Ball et al., 2008) and the CCSSM SMP. For example, when the interviewee discussed student misconceptions or observations of students, the comment was coded as KCS. If the teacher discussed problem solving strategies or perseverance, the comment was coded MP1 (Mathematical Practice 1: Make sense of problems and persevere in solving them). Both the MKT descriptors and full descriptions of the SMP can be found in Appendix A.

Next, I underlined key phrases that emphasized the main idea of each comment and summarized each participants' responses. This reduction was completed twice, with the intention of reducing the data and focusing in on key ideas while eliminating extraneous information. For example,

We needed to discuss the accuracy of measuring—they were leaving gaps. I also pointed out that starting at the beginning or end of the table makes it easier to be more accurate. One student noticed that too. Referring back to these during our discussion helped them when we went back to measure again

was summarized as “*discuss the accuracy of measuring*” and then coded as SCK). I also recorded memos as I noted trends in the decision-making process, similarities and differences between matched-pair participants, and overall comments regarding the professional development.

Third, I coded the reflections using the MKT categories (Ball et al., 2008) or the SMP from the CCSSM (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). A table including descriptors for each category was created to guide this work (see Appendix A for the MKT categories and the SMP list). As was the case for all qualitative analyses in this study (interviews, field notes, and participant reflections), the comments coded for the SMP typically qualified as subcategories for the MKT category KCS, so these were eventually incorporated into that category.

When using these categories, it became evident that although the teachers were accurate in placing their decisions into the two main categories, Subject Area Knowledge (CCK, SCK, HCK) or Pedagogical Content Knowledge (KCS, KCT, or KCC), they had difficulty distinguishing between the subcategories within them. Although this lack of understanding may warrant future investigation, the discrepancy seems irrelevant for the purposes of the current study.

Once the interview data had been coded and summarized, tables were created to combine the data for each group. Comparing the matched pairs directly to one another individually facilitated comparisons across the two groups. For instance, a comparison chart was created to examine the frequency with which each of the MKT categories occurred (Table 6).



Table 6  
*Frequency of MKT Categories Occurring in Stimulated-Recall Interview Data*

MKT category	Frequency	
	Experimental	Control
CCK	1	
SCK	2	1
KCT	7	10
KCS	4	4
TOTAL	14	15

As can be seen in Table 6, the frequencies for each category are quite similar between the experimental and control groups. Therefore, I went one step further and coded each for whether the data revealed an awareness and acceptance of reformed mathematics teaching principles as discussed in the MKT literature (+) or revealed a lack of awareness or acceptance of these principles (-). When this analysis was completed, 79% of the data in the experimental group exhibited positive examples of awareness (11/14), whereas only 47% of the data from the control group exhibited examples of an awareness or acceptance of these principles (7/15). Samples of awareness and acceptance of the MKT descriptions from the data include the following.

- The teacher allowed a student to explain her solution incorrectly in hopes that the student would catch her own mistake (KCS).
- The teacher asked other students to help a struggling student, and a variety of solution strategies emerged (KCT).
- The teacher selected the work from students at different levels for presentation—direct models, counting strategies, derived facts (KCT).
- The teacher created a table to help students “see” the emerging patterns (KCS, KCT).

Examples of teachers using techniques that revealed a lack of either awareness or acceptance of the reformed mathematics teaching principles discussed in the MKT descriptors include the following.

- The teacher deliberately provided a review of the traditional subtraction algorithm for students as they were struggling with the use of alternative algorithms, stating that she believed only her “high” students could understand the alternative algorithms, as opposed to what was stated by her matched-pair counterpart (KCS).
- The teacher selected and sequenced the presentations poorly—she should have chosen the visual representation to present first to prevent confusion as was done in her matched-pair class (KCT).
- The teacher provided rote practice of doubles facts when the students did not discern a doubling pattern, rather than allowing them to explore the pattern in a different way, as was done in the matched-pair class (KCT).

Once the analysis described above was complete and discernable differences were established, direct comparisons were made between the teachers in each matched pair.

### **Question 3: Indicators of Changes in Student Learning**

Similar to the process used for Question 2, the field notes and participant reflections provided qualitative support for changes in student learning based on the participants’ and my conceptions. However, the need to obtain objective data based on a quantitative student assessment was legitimate (Guskey, 2000). Therefore, data collected with the district’s benchmark assessment system, generally called *Galileo*, were examined to determine differences in student learning between the students whose

teachers were assigned to the experimental and control groups. This assessment was administered three times during the study: October 17, February 1, and May 8.

**Measure of student knowledge: Galileo benchmark assessments (Galileo).** To gauge the impact of the professional development treatment on student's mathematics learning, I used the classroom means from the Galileo student assessment to compare the treatment to the control classrooms as well as to compare the two treatment groups. The Galileo Educational Management System was designed to indicate which state standards have been mastered, to diagnose those standards needing further instructional attention, and to forecast performance on state standardized assessments (Bergan et al., 2011). Using IRT, the Galileo assessment assigns student results a developmental-level score that serves as a scaled score, allowing progress tracking across a series of benchmark assessments.

The Galileo assessment forms used for this study were aligned with the 2008 Arizona Mathematics Standard rather than the CCSSM. Therefore, it was used only as a means to compare the study participants' classes as opposed to identifying student performance based on the CCSSM. The Arizona Mathematics Standard (Arizona Department of Education, 2008) included the following domains: Number Sense and Operations; Data Analysis, Probability, and Discrete Mathematics; Patterns, Algebra, and Functions; Geometry and Measurement; and Structure and Logic. Although the Arizona Mathematics Standard includes references to the NCTM Process Standards, these were not directly addressed on the assessment. Note that an analysis of the content of the Galileo indicated that each form had about a 75-80% overlap with the CCSSM, depending on the form.

The psychometrics for the Galileo are evaluated each time a benchmark assessment is implemented. At the time of this writing, neither the validity or the reliability data were available for inclusion. However, descriptions for the analysis process included the following.

- A validity analysis was conducted using student data from the 2007–2008 school year to determine the validity of using the Development Level Score as a measure of progress. Mean scores were determined for 25,769 students across 66 school districts. When placed on a common scale, the results provided support that within each grade level, positive changes in performance occurred.
- Research conducted by the Galileo authors has indicated that the assessments of at least 50 items yield reliability coefficients between .8 and .9. The benchmark assessments used for this study had 52 items.

All study participants administered the Galileo assessments in October, January, and May, according to their district guidelines. The district-directed assessment cycle coincided with the two treatment cycles in this study, with the first administration occurring the week prior to the initial treatment, the second administration occurring between the end date of the initial treatment and the start date of follow-up treatment, and the third administration occurring the week following the conclusion of the follow-up treatment. Although all forms of this assessment were aligned to the state standards in place prior to the CCSSM, use of these assessments still allowed for control of the

treatment and control group means, allowing for detection of differences in student scores.

To detect an effect of the CCSSM professional learning structure on student learning in the classes of participating teachers, a repeated measures ANOVA was conducted on the scores from the Galileo benchmark assessment administered before Treatment 1, between treatments, and after the replication treatment. The results of this analysis appear in Chapter 4. Note that the class scores for one participant from the treatment group were not included in this analysis as she went on maternity leave on the morning of the last day of the treatment, just a few days prior to her students taking the Galileo benchmark assessment being used as a posttest. The students performed very poorly on the test, moving in a negative direction far exceeding that of any other class in this study. Given the precarious testing conditions with young children under the direction of a substitute teacher, the class's mean score was considered an outlier and excluded for this analysis.

### **Additional Data Sets**

In addition to the measures of teacher knowledge, indicators of classroom practice, and measure of student learning, two other data sets were used to substantiate and triangulate the findings regarding changes in teacher knowledge, classroom practice, and student learning. Written participant reflections and researcher field notes, described below, provided further evidence that the treatment positively impacted the teachers and their students regarding all three research questions and provided information regarding work yet to be addressed with this group of teachers. Note that with the analysis for each of these two data sets, the data were combined across the two treatments because the

second treatment was a replication of the first. Care was taken to ensure that the treatments were treated as similarly as possible, using the same lesson plans, activities, scheduling, and so on. To further synchronize the two treatments, I listened to the recorded field notes from the initial treatment prior to each follow-up session, providing a basis for combining the data sets from the two treatments.

**Participant reflections.** Participants completed daily reflections at the start and end of each professional learning session. In addition, they completed extended reflections at the beginning of Session 4 and the end of Session 6, with a focus on their conceptions of the impact of the professional development model on their knowledge of the standards and the impact of their new knowledge on classroom implementation and student learning. For the purposes of this study, four questions from the extended reflection on Session 6 were selected for analysis:

1. What impact has the course had on your knowledge of the second-grade math curriculum (defined as the Common Core State Standards for Mathematics)?
2. What impact has your new knowledge had on your teaching?
3. What impact has your new knowledge had on student learning in your classroom?
4. Using the Mathematical Knowledge for Teaching diagram, explain how your knowledge of teaching math has changed as a result of participating in this class.

Note that 16 participants from the experimental group and 11 participants in the control follow-up group submitted final reflections. The reasons for nonsubmissions included

maternity leave (one from each group), early departures (two from the experimental group), and nonsubmissions (seven from the follow-up treatment group).

In preparation for these questions, the participants were exposed to the MKT chart (Figure 10) and provided with opportunities for reflection on their learning and practice several times prior to the last day of class. The responses to these questions were analyzed using the constant-comparison method (Dye et al., 2000). This method is described at length in Chapter 4.

The participant reflections were analyzed using the constant-comparison method, an analysis process widely used in qualitative research (Dye et al., 2000; Lincoln & Guba, 1985; Patton, 1990). Although often associated with grounded theory, this analytic method is one of the most commonly used in qualitative research, well beyond the grounded theory tradition (Leech & Onwuegbuzie, 2007). The process is used in three stages. During the first stage, open coding, the analyst chunks the data into smaller segments and assigns labels, or codes, to each. One may use a deductive process, identifying starting codes before the analysis begins, or one may inductively identify the codes during this first phase. During this stage, the analyst attends to the codes assigned to each data chunk, looking for opportunities to assign the same code to data chunks with similar content. During the second stage, axial coding, the analyst groups the coded data into similar categories. During the third stage, selective coding, the analyst integrates and refines the themes that emerged during the first two stages (Leech & Onwuegbuzie, 2008).

I used a cross-case analysis, rather than a case-by-case analysis, to detect trends across the two groups, initial treatment and follow-up treatment (Dye et al., 2000).

Answers to common questions were grouped and analyzed to discern different perspectives on central themes. The overall process included three stages: (a) open coding with the initial treatment group's reflections, one question at a time, followed by open coding with the follow-up treatment group's reflections, one question at a time, (b) axial coding across each question, initial treatment group followed by the follow-up treatment group for each question, and (c) selective coding throughout the entire data set, refining the categories and themes that had emerged during the first two stages. The process used closely resembles the procedure outlined by Dye et al. (2000).

During the first stage, I chunked the responses from the experimental group into single-topic segments and assigned codes to each. Comparisons between data segments aided with the code assignments of each subsequent segment, resulting in the temporary grouping of data representing similar content. This was done separately for each of the four reflection questions being analyzed within the experimental group's data.

During this process, code definitions were considered and revised. For example, the following three statements were all assigned the same KCS code.

- “This course has helped me to shift my own understanding of math and what second graders are capable of.”
- “To fully engage students in the learning process, they need time to explore and use manipulatives to construct their understanding of the skills/concepts that are taught in second grade.”
- “It has taught me to think about common misconceptions that my students may have as they get older.”



The initial code selected for these segments was KCS, borrowed from the MKT framework developed by Ball et al. (2008). Other codes used for Question 1 during this initial stage included KCT, KCC, classroom activities, interactive workshop activities, participant confidence, and participant eagerness. Similar codes, as well as unique codes, evolved for Questions 2 through 4.

Once completed for the experimental group data set, this process was repeated using the control follow-up participant reflections. Although this second data set was coded separately, comparisons were made to the treatment group's codes, noting similarities as well as the need for possible revisions.

Toward the end of this first stage, preliminary code rules were established that encompassed the data for both the experimental and the control follow-up groups. For the codes that came from the MKT framework (Ball et al., 2008), an MKT guide was created from the literature, including descriptors of the characteristics for each of the six categories (see Appendix A). For the codes based on the common core SMP, the CCSSM document was used to guide the coding process. A summary of the SMP codes can be found in Appendix A. For the codes unique to this study, such as confidence, eagerness, classroom activities, and interactive workshop activities, rules for inclusion were listed in an Excel spreadsheet.

At this point, Stage 2 commenced with the formal grouping of data into categories. I read through all data segments again, formally assigning them to the emerging categories. This was done for the initial treatment group's responses to Question 1, followed by the follow-up treatment group's responses to the same question. While working with the data from both groups, several categories were adjusted and

renamed to further clarify the meaning of each category. Once this process was completed for Question 1, Questions 2, 3, and 4 were completed in the same fashion.

Throughout the above process, I integrated data groups that contained only one or two comments into other groups or combined them to form new categories. For example, only one of the follow-up treatment participants had commented on her eagerness to implement the course content, and two had commented on their increased confidence as a result of this course. Therefore, these two codes were combined into one category called “dispositions,” with “eagerness” and “confidence” identified as subcategories.

After carefully scrutinizing the data in each category, the category list and inclusion rules began to solidify. I once again read both data sets to confirm, change, or remove existing categories and create new ones. Then I devised rules for inclusion in these tentative categories. Similar to the code definitions created in Stage 1, these inclusion rules included two guiding documents: a matrix of the MKT categories (Ball et al., 2008) and the SMP from the CCSSM (National Governors Association for Best Practices & Council of Chief State School Officers, 2010). In addition, I created a third document defining the inclusion rules for the categories unique to this study. See Appendix A for the final list of codes, categories, themes, and inclusion rules for each of the four reflection questions.

Once again, before moving to Stage 3, I examined both data sets, refining the categories and developing subcategories. Occasionally, combining similar categories resulted in the original categories becoming subcategories. For example, KCS, KCT and KCC became subcategories of the newly established *pedagogical content knowledge*. This created more robust categories with more supporting data within each.

As Stage 2 come to an end, three themes began to emerge across the four questions: MKT (with the SMP for some questions), Perceived Dispositions, and Resources and Experiences. Note that not all three themes were represented within all four questions. Subcategories were created at this point, sometimes from combining similar categories and other times by splitting data within a preliminary category.

In the third stage, I directly compared the two groups' responses to each question, reexamining the relationships of the data sorted into each category within each group and across both groups. As the refinements became more focused, the rules for inclusion were clarified and finalized (once again, see Appendix A for final categories and inclusion rules). Each data segment was once again carefully scrutinized to ensure placement into the category of best fit. In addition, further refinements were made to the categories and subcategories, with attention afforded to the themes emerging during Stage 2. For example, during this stage, it became apparent that 74% of the respondents had responded to the second question, "How has your new knowledge impacted your teaching?" in a way that was characterized as *KCT*. This category needed to be further explored in order to truly address the question at hand. Therefore, the data segments in this category were reread and placed into subcategories to address the question. The same process was done for Question 3, "What impact has your new knowledge had on student learning in your classroom?" In this case, however, the responses were not subcategorized, but rather examined in light of the relationship between responses in the subcategory "knowledge of content and students" and the category "standards for mathematical practice."

At this point, all data was entered into a spreadsheet, making final adjustments to category assignments as dictated by the inclusion rules. Table 7 lists the themes, categories, and subcategories inductively produced from the data across all four questions as well as which of the four participant reflection questions addressed each category.

Table 7  
*Themes and Categories From Participant Reflection Analysis*

Themes	Categories—Questions providing evidence	Subcategories
Mathematical knowledge for teaching	Subject matter knowledge—Question 4	<ul style="list-style-type: none"> <li>• Common content knowledge</li> <li>• Specialized content knowledge</li> <li>• Horizon content knowledge</li> </ul>
	Pedagogical knowledge for teaching—Questions 1, 2, 3, and 4	<ul style="list-style-type: none"> <li>• Knowledge of content and students</li> <li>• Knowledge of content and teaching</li> <li>• Knowledge of content and curriculum</li> </ul>
	Standards for mathematical practice—Question 3	<ul style="list-style-type: none"> <li>• SMP1: Problem solving</li> <li>• SMP2: Reasoning</li> <li>• SMP3: Explaining</li> <li>• SMP6: Using precision</li> </ul>
Dispositions	Dispositions—Questions 1, 2, and 3	<ul style="list-style-type: none"> <li>• Confidence</li> <li>• Eagerness</li> <li>• Overwhelmed</li> <li>• Students</li> </ul>
Resources and experiences	Activities—Questions 1 and 2	<ul style="list-style-type: none"> <li>• Interactive</li> <li>• Classroom</li> </ul>

Once the data were compiled into a spreadsheet, I began quantifying the data. According to Miles and Huberman (1994), three good reasons exist for quantifying, or “counting,” qualitative data: (a) “seeing” what you have to contribute to your understanding of the data, (b) verifying a hypothesis or refuting preconceived notions, and (c) promoting honesty in analysis and interpretation by examining frequencies in light of my insights and intuitions. For this data set, quantification offered me insight into the perspectives of the participants as a whole group, allowing me to step back from my

interactions with the individuals and really attend to the response frequencies, thereby drawing more global conclusions.

Although this data are not generalizable to other groups, it provides supportive evidence for the participants' conceptions of the learning that took place during the treatment and contributes to the story told by the other data sets in this study. Tables in Chapter 4 indicate the percentages of participant responses within each category and subcategory for each of the four reflection questions analyzed.

**Field notes.** Following each professional development session, I recorded field notes recapping the events of the day, highlighting specific conversations and interactions. To increase the quality and accuracy of the field notes, I used lesson plans written prior to the session, notes taken during the session, and participant reflections completed at the end of the session to recap each session. The field notes were later transcribed and analyzed using sequential analysis (Miles & Huberman, 1994).

Field notes from both the initial treatment and the follow-up treatment were collected and analyzed with the objective of revealing the story that unfolded as the teachers experienced the treatment. I audiorecorded the field notes during the lunch break at the end of each training, based on the notes taken during the session(s) as well as recollections of interactions, conversations, and activities from the day. The audio notes were transcribed and entered into a spreadsheet for analysis. The sequential analysis method provided the framework by which the data were analyzed (Miles & Huberman, 1994). Note that the field notes from the initial treatment also served as a preparation tool for the facilitation of the follow-up treatment as I listened to the field notes from each session in the initial treatment prior to replicating the corresponding session with the

follow-up group. This served to ensure consistency between the two treatments and provided for the opportunity to combine the field notes from the two treatments to tell one, robust story.

The sequential analysis method uses indicative coding and a grounded approach, with the goal of deriving theory (Chesler, 1987). The process includes data reduction, coding, and generalizing, and allows the researcher to observe trends in data collected over a period of time. The following steps comprise the sequential analysis method.

1. Underline key terms in the text.
2. Restate key phrases.
3. Reduce the phrases and create clusters (may be done several times).
4. Reduce the clusters and attach labels (pattern coding).
5. Make generalizations about the phrases in each cluster.
6. Generalize mini-theories: memo writing that poses explanations.
7. Integrate theories in an explanatory framework (refer to the literature base)

(Miles & Huberman, 1994, p. 87).

As was done with the participant reflections, a cross-case analysis was conducted, rather than a between-case analysis, with the intention of detecting the overall impact of the professional development. This decision was primarily based on the replication nature of the follow-up with the control group. The field notes recordings, lesson plans, and time logs were used in the professional development design to replicate the same experiences for both groups. Therefore, few differences occurred.

As the analysis commenced, the field notes were placed into separate spreadsheets for each day of training, for a total of 11 days, 5 days for the initial treatment and 6 days

for the follow-up (note that the field notes from the first day of the initial treatment were accidentally erased). For each day, the data were broken into single-episode segments. A segment may have included a conversation, an interaction, an activity, or the like. Occasionally, episodes were further segmented so as to capture single ideas from each data chunk.

Next, Steps 1 through 3 from the sequential analysis method (underlining, restating, and reducing) were repeated four times in an effort to concentrate on the themes that emerged from the conceptions of the impact of the professional development on teachers' knowledge, classroom practice, and student learning. Preliminary categories were used, beginning with the categories created for the participant reflection analysis. The categories that emerged included (a) MKT, (b) dispositions, (c) activities and instruction, (d) district support, (e) presenter reflections, and (f) extraneous text. Eventually, the presenter reflections and extraneous text were eliminated from the usable data set. Using an iterative process of summarizing, coding, and reducing, subcategories and rules for inclusion emerged. See Appendix A for a complete list of codes, categories, themes, and inclusion rules for each of the four reflection questions.

Eventually, all of the summary segments were moved into one spreadsheet and were clustered together using the established labels. This allowed me to discern which segments addressed at least one of the research questions and which were irrelevant.

### **Summary**

The analysis of each individual data set explained thus far provided a view of the impact of the treatment through a different lens. However, collectively, they provided an opportunity to assess the theory of change set forth in Chapter 1 by examining different

focal points, including teacher knowledge, instructional change, and student achievement. When combined into a cohesive model, the story regarding the relationship between professional development and its impact emerged at multiple levels. This story will be explored further in the discussion in Chapter 5.

Table 8 summarizes the procedures used to collect data for each instrument described in the previous section. The collection method and the timeline are included to provide a frame of reference for how the data collection interfaced with the treatment. Note that the initial treatment occurred between October 27 and January 24, and the follow-up treatment took place between February 9 and May 3.



Table 8  
*Procedures for Data Collection*

Data set	Collection method	Timeline
		Initial treatment training dates: October 27, November 10, 29, December 15, January 10, 24 Follow-up treatment training dates: February 9, March 6, 20, 29, April 12, May 3
LMT	Online assessment taken either in a proctored lab setting or independently (designated under timeline)	1. October 27 (experimental group); October 27–November 3 (control group, independently) 2. January 24 (experimental group); February 9 (control group) 3. May 3 (control group); May 1–8 (experimental group, independently)
Sorting task	Online assessment taken either in a proctored lab setting or independently (designated under timeline)	1. October 27 (experimental group); October 27–November 3 (control group, independently) 2. January 24 (experimental group); February 9 (control group) 3. May 3 (control group); May 1–8 (experimental group, independently)
Galileo benchmark assessment	Paper-pencil assessment administered three times by teachers using standardized district protocols	Testing window for each assessment: 1. October 17–21 2. January 30–February 3 3. May 7–11
RTOP	Observation protocol completed by external evaluator	Four teachers per day: 1. December 6 & 8 2. January 17 & 18 3. February 3 & 6
Stimulated-recall interview	Interview protocol audiotaped by external evaluator	Four teachers per day: 1. December 6 & 8 2. January 17 & 18 3. February 3 & 6
Field notes	Audio notes recorded by researcher after each session	Recorded after each session, 11 sessions total (I missed the first session of the initial treatment)
Participant reflections	Written responses completed on the last day of the professional development	January 24 (experimental group) May 3 (control group)

*Notes:* RTOP = Reformed Teaching Observation Protocol.

## CHAPTER 4

### RESULTS

In the ongoing quest to determine the relationship between professional development and teacher knowledge, classroom practice, and student learning, analysis for this study fell into four categories:

1. statistical comparisons of changes in teacher knowledge and student learning between the experimental and control groups during the fall semester,
2. statistical comparisons of the changes in teacher knowledge and student learning between the teachers participating in the initial treatment during the fall semester (experimental group) and those participating in the follow-up treatment during the spring semester (control group),
3. descriptive comparisons of four case studies of matched pairs intended to detect differences in individual teachers and classroom practice as a result of the treatment during the fall semester, and
4. descriptive analyses of perceived changes in teacher knowledge, classroom practice, and student learning that occurred during both semesters.

Quantitative and qualitative instrumentation and analytic methods were used in the analysis process.

To keep with the flow of Chapter 3, the data analysis and results appear in the same order as the three research questions: teacher knowledge, classroom practice, and student learning. Because the participant reflections and field notes analyses address all questions, they appear at the end of this chapter. Table 9 summarizes the analysis configurations for each data set.

Table 9  
*Data Sets Analyzed*

Research question	Instrument	Participants	Comparisons
1. Impact on teacher knowledge	LMT scales	All	Treatment/Control; Initial Treatment/Follow-up
	Sorting Task	All	Treatment/Control; Initial Treatment/Follow-up
	Reflections	All	N/A (combined)
	Field Notes	All	N/A (combined)
2. Impact on classroom practice	Observations	Matched Pairs	Treatment/Control
	Interviews	Matched Pairs	Treatment/Control
	Reflections	All	N/A (combined)
	Field Notes	All	N/A (combined)
3. Impact on student learning	Galileo	All	Treatment/Control; Initial Treatment/Follow-up
	Reflections	All	N/A (combined)
	Field Notes	All	N/A (combined)

Taken as a whole, the instrumentation and analyses comprise four of the five levels of professional development evaluation described by Guskey (2000): participants’ reactions, participants’ learning, participants’ use of knowledge, and student learning outcomes. Although organizational support and change were not directly examined in this study, the qualitative analyses did reveal hints of this category that will be included as part of the discussion in Chapter 5.

### **Measures of Teacher Knowledge**

#### **Participants’ Mathematical Knowledge for Teaching**

A repeated measures ANOVA was conducted to compare the effect of group assignment (experimental, control) on the change in LMT score in pre- and posttest conditions during the initial treatment. There was a significant effect of group assignment on the difference between the pre- and posttest scores at the  $p < .05$  level [ $F(1, 30) = 4.406; p = .044$ ], with the effect calculated as 0.7730 using Cohen’s  $d$  (Cohen, 1988). These results suggest that there is a statistically significant difference between the

teachers included in the experimental group ( $Mean_{Gain} = 0.54$ ,  $SD = 0.94$ ) and the teachers in the control group ( $Mean_{Gain} = -0.07$ ,  $SD = 0.59$ ) in the LMT pre–post score differences. Table 10 indicates the gains in means between the pre- and posttest for the experimental and the control groups.

Table 10  
*Gains in Group Means for the LMT Scale—Initial Treatment*

	Pre	Post	Gain
Experimental ( $n = 18$ )	-0.404139	0.131794	0.5361
Control ( $n = 13$ )	-0.748871	-0.818807	-0.0707

In addition to conducting a repeated measures ANOVA to compare the experimental and control groups during the initial treatment, I also conducted a similar test to determine the growth rate of the control group during the follow-up treatment that took place during the spring semester. There was a significant effect on the difference between the pre- and posttest scores at the  $p < .05$  level [ $F(1, 18) = 5.965$ ;  $p = .025$ ], with the effect calculated as 0.5933 using Cohen’s  $d$  (Cohen, 1988). These results suggest that there is a significant difference between the pretest scores ( $Mean_{pre} = -0.922705$ ,  $SD = 0.6859161$ ) and the posttest scores ( $Mean_{post} = -0.482989$ ,  $SD = 0.7924021$ ) in the LMT pre–post score differences. Because a different number of participants completed the LMT in each administration, cases were analyzed listwise so that only those participants who took the midyear pretest and the last posttest were included. Table 11 indicates the mean gains for the follow-up treatment during the spring semester.

Table 11  
*Group Means for the LMT Scale—Follow-up Treatment*

	Pre	Post	Gain
Control (follow-up) ( $n = 19$ )	-0.922705	-0.482989	0.4397

Taken together, the data reveal that there was a positive gain in LMT scores for the experimental group in the initial treatment ( $Mean_{Gain} = 0.54$ ,  $SD = 0.94$ ) as well as for the control group in the follow-up treatment ( $Mean_{Gain} = 0.44$ ,  $SD = 0.78$ ), with Cohen's  $d$  effect sizes of 0.7730 and 0.5933, respectively. This outcome suggests that the treatment has a positive impact on teachers' MKT in for both groups.

### **Participants' Knowledge of the Standards**

An independent  $t$ -test was conducted on the results of the online sorting task. This provided a means to compare the effect of group assignment (experimental, control) on the change scores in pre- and posttest conditions during the initial treatment, as determined by finding the difference between positive and negative growth scores. There was a significant effect of group assignment on the difference between the pre- and posttest scores at the  $p < .05$  level [ $t(29) = 3.322$ ;  $p = .002$ ], with the effect calculated as 1.2539 using Cohen's  $d$ . These results suggest that there is a significant difference between the teachers included in the experimental group ( $Mean_{Growth} = 7.2222$ ,  $SD = 3.6722$ ) and the teachers in the control group ( $Mean_{Growth} = 3.3846$ ,  $SD = 2.29269$ ) in sorting task pre-post growth differences.

As can be seen in Table 12, the control group, which participated in the professional development during the follow-up treatment, made a gain score of 3.38 during the fall semester, prior to receiving the follow-up treatment. Table 13 shows an additional net growth of 3.17 for the control group after their follow-up treatment. Although there was a statistically significant difference between the experimental and control groups after the first treatment, this growth score indicates that some learning took place in the control group prior to the follow-up treatment. Therefore, I ran an

additional *t*-test to compare the experimental and control-turned-replication groups over the entire year (see Table 14). Because a different number of participants completed the sorting task in each administration, as explained in Chapter 3, cases were analyzed listwise so that only those participants who took the first pretest and the last posttest were included.

Table 12  
*Group Means for the Online Sorting Task—Growth Scores (t-Test)—Initial Treatment*

	Positive growth	Negative growth	Net growth
Experimental ( <i>n</i> = 18)	10.89	3.67	7.22
Control ( <i>n</i> = 13)	8.38	5.0	3.38

Table 13  
*Group Means for the Online Sorting Task, Follow-up Treatment*

	Positive growth	Negative growth	Net growth
Control (follow-up) ( <i>n</i> = 18)	7.84	4.67	3.17

Table 14  
*Group Means for the Online Sorting Task, Experimental Group vs. Control (Follow-Up) Group*

	Growth score from October to January	Growth score from January to May	Growth score from October to May
Experimental ( <i>n</i> = 17)	7.0588	-1.4118	5.2353
Control (follow-up) ( <i>n</i> = 13)	3.3846	2.7692	5.2308

In addition to conducting an independent *t*-test to compare the experimental and control groups, I also considered the growth score for the control group during the follow-up treatment that took place during the spring semester. Furthermore, upon examination of the posttreatment scores for both groups, this independent *t*-test revealed that there was no statistical difference between groups once both had completed the treatment at the  $p < .05$  level [ $t(28) = ; p = .997$ ], with the effect calculated as 0.00149

using Cohen’s *d*. These results suggest that there is no significant difference between the teachers who received the initial treatment (experimental group;  $Mean_{Growth} = 5.2353$ ,  $SD = 3.49159$ ) and the teachers in the follow-up treatment (control group;  $Mean_{Growth} = 5.2308$ ,  $SD = 2.45472$ ) in the sorting task pre–post growth differences from the beginning of the first treatment to the end of the replication study. In summary, these results reveal that both the experimental group and the control follow-up group had learned at the same level after both had received the treatment.

### Indicators of Classroom Practice

#### Reformed Teaching Observation Protocol

The intended outcome for the observations encompassed the collection of evidence to confirm or disconfirm that differences existed between the teachers from the experimental and their matched control teachers during the fall semester. Therefore, I calculated mean scores for each observed teacher across the three observations (two observations for one of the matched pairs) to get a stable rating of the overall classroom practice for each teacher. The scores for each teacher appear in Table 15.

Table 15  
*RTOP Scores for Four Matched Pairs*

Pair-group	RTOP 1	RTOP 2	RTOP 3	TOTAL	Mean
1-E	41	44	54	139	46.333
1-C	19	27	22	68	22.667
2-E	11	19	N/A	30	15
2-C	5	9	N/A	14	7
3-E	65	55	59	179	59.667
3-C	45	37	39	121	40.333
4-E	17	5	13	35	11.667
4-C	7	7	10	24	8

*Notes:* E = Experimental; C = Control; RTOP = Reformed Teaching Observation Protocol.

An ANOVA was performed using the mean RTOP score as the outcome and then blocking on each matched pair to factor out the effects of similar school and LMT pretest scores. Taking into account prior MKT and the potential that teachers from the same school would have similar work conditions, including student demographics, professional development experiences, and curricular constraints, teachers in the treatment group outperformed teachers in the control group. ( $p < .05$ ). Looking at the SSError compared with the SS per group, much of the error is accounted for by the similarities among teachers, defined previously (same school and similar LMT pretest score). Table 16 indicates the results of the ANOVA for the matched pairs.

Table 16  
*ANOVA Table Comparing RTOP Scores for Matched Pairs of Experimental and Control Teachers*

Source	Sum Sq.	d.f.	Mean Sq.	<i>F</i>	Prob > <i>F</i>
Experimental vs. Control	38.281	1	38.2812	10.65	0.047
Pairs used as Blocks	230.122	3	76.7072	21.33	0.0159
Error	10.788	3	3.5961		
Total	279.191	7			

Notes: RTOP = Reformed Teaching Observation Protocol.

This indicates that a statistical difference existed between the teachers selected from the experimental group and their matched pairs in classroom instruction, indicated by the RTOP. In addition to calculating the scores for each teacher, I used the RTOP to stimulate a discussion with each participant subsequent to each interview, explained below.

### **Semistructured Stimulated-Recall Interview Protocol**

Upon completion of coding and summarizing the interview data, the frequencies for each category were quite similar between the experimental and control groups. As



described in Chapter 3, the frequencies were subsequently coded for whether the data revealed an awareness and acceptance of reformed mathematics teaching principles, as discussed in the MKT literature (+), or revealed a lack of awareness or acceptance of these principles (-). See Appendix A for the MKT descriptors. This analysis revealed that 79% of the data in the experimental group exhibited positive examples of the presence of MKT descriptors (11/14), whereas only 47% of the data from the control group exhibited examples of an awareness or acceptance of these principles (7/15). Once the analysis process described in Chapter 3 was complete and discernable differences were established, direct comparisons were made between the teachers in each matched pair.

**Matched Pair 1.** When comparing the interview data for the first matched pair, evidence that any differences existed was elusive. Of the four pairs, these two were the highest scoring teachers on the LMT. Both provide evidence of using SCK, KCS, and KCT in the descriptions of their decisions. At one point, each mentioned that students were having difficulty explaining their answers, so they asked guiding questions because the rest of the class was “squirming” and getting “antsy.” This revealed that they monitored class behavior, and when a shift was required, they knew to ask clarifying questions rather than resorting to providing answers or simply moving on with no clarification for the student. Another similarity revealed through the interviews was that both teachers referenced direct modeling, counting strategies, and derived facts during their interviews.

**Matched Pair 2.** The second matched pair represented the lowest scoring in this analysis on LMT and one of the lowest scoring pairs on the RTOP. Note that this is also the pair that I only observed and interviewed twice because the teacher from the

experimental group went on maternity leave the week prior to the final observation. Although both of these teachers appeared to be weak in their implementation of the categories described in the MKT descriptors (see Appendix A), a couple of interesting distinctions emerged. During the second interview, both teachers had students experiencing difficulty with the mental mathematics lesson they were facilitating. Upon facing the need to make a decision, the teacher from the experimental group discontinued the mental mathematics segment because students were relying too hard on the standard algorithm for subtraction. The teacher was unsure as to how to proceed, stopped for the time being, noting wanting the students to explore alternative algorithms, but needed to work on how to facilitate those discussions. In contrast, the teacher from control group decided to change gears and model the standard algorithm for subtraction when students struggled with the alternative algorithms. The teacher stated that students were struggling, so wanted to introduce them to the standard algorithm, and then they could figure out alternative ways to solve later. The control teacher also noted that only “high” students were ready to work with alternative algorithms, and that the teacher did not like to teach then, anyway.

The distinction here is the rationale for why they did what they did, with the treatment teacher wanting students to use alternative algorithms but unsure as to how to draw it out from them, and the control teacher wanting to show the standard algorithm because the alternative algorithms were hindering the students. Although neither appeared to be skilled in facilitating the use of alternative algorithms or the discussions leading to their development, the treatment teacher was aware of the desirability to move in that direction.

**Matched Pair 3.** The third matched pair provided much more of a contrast than the first or second. The most experienced of the teachers in this analysis (23 years and 15 years, respectively), and the highest scoring on the RTOP, differences in their decisions and rationales was clear. During the first observation/interview, they presented the same lesson, based on the book, *Two of Everything*, with the purpose of having students work on doubling numbers. Both found their students were struggling. The teacher from the experimental group chose to create a table of clues to help the students “see” the doubling pattern as it emerged. The teacher from the control group, in contrast, chose to present the students with verbal totals, to which they were supposed to respond verbally with the associated doubles fact. The first teacher noted that students began to experience success when they could “see” the patterns in the chart, whereas the second teacher noted that students still needed more practice with doubles facts, especially with the total provided.

During the second observation/interview, both teachers noted that they needed to review how to accurately measure with nonstandard units. The teacher from the experimental group took more of a student-centered approach (led discussion, but allowed the students to suggest ways to be more accurate), whereas the teacher from the control group took a more teacher-led approach (“I reminded them to stack the units end-to-end, keep them flat, count them accurately”). The control teacher also mentioned that it would be easier to use rulers: “Using the strips of paper drives me nuts. I’d rather just go right into using the tool.”

During the third observation/interview, both teachers stopped student work to provide guidance with challenges most students were experiencing. The teacher from the experimental group noticed that students were having difficulty solving word problems

that were not all the same problem types (result-unknown, change-unknown, start-unknown); the experiment teacher guided students in finding critical information and in paying attention to the question. The teacher from the control group had students measure objects and stopped them to watch the teacher measure a pair of scissors on the overhead projector because they all had different kinds of scissors and were, therefore, getting different measurements, rather than allowing students to discuss or grapple with inconsistent data.

These three examples provide evidence that the teacher in the experimental group interpreted students' emerging and incomplete thinking and evaluated the instructional advantages of representations, both descriptors in the MKT chart. In contrast, the teacher from the control group discussed decisions that are in opposition to the intentions of the MKT descriptors, including poor choices in interpreting students' emerging and incomplete thinking and in choices for selecting and sequencing examples.

**Matched Pair 4.** The fourth pair of teachers tended to discuss management issues during their interviews rather than decisions that were focused on mathematics content and pedagogy. Decisions they focused on included the way they, themselves, drew pictures on the board, the way they ordered presentations, and the poor questions they chose to ask. However, in two separate observation/interviews, their discussion of teacher demonstration showed one unique difference. The experimental teacher decided to demonstrate how to draw pictures to represent division after the students had been given time to try on their own but were unsuccessful in solving the given problems. In contrast, the teacher from the control group directly modeled counting strategies prior to giving the students the opportunity to use solution paths of their own choosing, stating that even

adults have trouble with this concept. This provided possible evidence that the teacher in the experimental group had a grasp of how to evaluate the instructional advantages of representation and when to pause or ask a new question, whereas the control teacher sequenced instruction in such a way as to neglect to provide opportunities for students to attempt to develop their own solution strategies.

In summary, as seen with the RTOP results, discernible differences existed between teachers in the experimental and control groups, with the exception of the first matched pair, where there was a difference in RTOP scores, but not in the interview analysis. Given that these observations and interviews were conducted during Months 2 and 3 of the first treatment, little difference would be expected; yet the treatment group appeared to be implementing strategies in line with the MKT indicators at a higher rate than the control group (79% and 47%, respectively). These results are not generalizable, but they do reveal a distinction between the two groups of teachers.

### **Measure of Student Learning**

A repeated measures ANOVA was used to determine differences in student performance between the experimental and comparison groups' classes, based on pre-post scores of the Galileo student assessment. I entered group assignment (experimental or control) as the independent measure, and specified pre- and posttest scores as the dependent measures in the repeated measures ANOVA.

The repeated measures ANOVA showed a nonsignificant effect of group assignment on the difference between the pre- and posttest scores at the  $p < .05$  level [ $F(1, 35) = 0.762$ ;  $p = .451$ ]. These results suggest that there is no significant difference between the classes of teachers included in the experimental group ( $Mean_{Gain} = 31.8844$ ,

$SD = 20.81781$ ) and the teachers in the control group ( $Mean_{Gain} = 26.7084$ ,  $SD = 20.49949$ ) in the Galileo pre–post score differences. Using the means and the standard deviations, Cohen’s  $d$  was calculated as 0.25054. This indicates that no significant relationship was found between the treatment and student learning, measured by the Galileo Benchmark Assessments.

Table 17 shows the Galileo Benchmark Assessment means of the participants’ classes administered during the fall semester (October and February).

Table 17  
*Group Means for the Galileo Benchmark Assessments (Administered in October and February)*

	Pre	Post	Gain
Experimental ( $n = 18$ )	639.1578	671.0422	31.8844
Control (follow-up) ( $n = 19$ )	643.4142	670.1226	26.7084

In addition to conducting a repeated measures ANOVA to compare the Galileo scores of the classes of participants in the experimental and control groups during the first treatment, I also looked at the growth rate that took place during the follow-up treatment, illustrated in Table 18.

Table 18  
*Group Means for the Learning Mathematics for Teaching Scale, Experimental Group vs. Control (Follow-up) Group (Administered in February and May)*

	Pre	Post	Gain
Experimental ( $n = 18$ )	671.0422	723.9517	52.9095
Control (follow-up) ( $n = 19$ )	670.1226	721.8568	51.7342

The results shown in Table 18 reveal that during the second semester, once the teachers in both the experimental and control groups had participated in the treatment, the gain scores for their students were very similar. Table 17 indicates that a difference of

5.176 was detected between growth scores during the initial treatment in the fall, whereas Table 18 indicates that a difference of only 1.1753 resulted during the follow-up treatment in the spring. Although there was not a statistically significant difference between the treatment and control groups in the fall, the decreased mean differences from the fall to the spring provide grounds for further investigation, perhaps with a larger sample, as well as examination across a longer duration of time.

### **Participant Reflections and Field Notes**

Although the data collected from the participant reflections and field notes is not generalizable to other groups, it provides supportive evidence for participants' conceptions of the learning that took place during the treatment and contributes to the story told by the other data sets in this study. For the following analyses, the inclusion rules for the participant reflections and the cluster codes for the field notes can be viewed in Appendix A. Although the analyses were conducted separately using different analytic methods, the inclusion rules and cluster codes were purposely coordinated to better triangulate the data.

#### **Participant Reflections**

Once the process described in Chapter 3 was completed, frequency charts were created to indicate the percentages for participant responses that occurred in each category and subcategory for each of the four reflection questions. Note that these tables represent the percentage of participants who addressed each category, with several instances where single participants responded to multiple categories in the same table. Therefore, the category tables do not each add to 100%.

Tables 19 and 20 summarize the participant data for Question 1, “What impact has the course had on your knowledge of the second-grade math curriculum (defined as the CCSSM?” Table 19 lists the overall categories addressed by each group of participants, along with the percentage of each group of participants that addressed each category, combined and individually. Table 20 includes the subcategories that were addressed by each group of participants, including the percentage of participants addressing each subcategory.

Table 19

*Responses to Question 1 by Category: What Impact Has the Course Had on Your Knowledge of the Second-Grade Math Curriculum (Defined as the Common Core State Standards for Mathematics)?*

Categories	Total (n = 27)
Pedagogical content knowledge	88.89%
Dispositions	33.33%
Activities	37.04%

Table 20

*Responses to Question 1 by Subcategory: What Impact Has the Course Had on Your Knowledge of the Second-Grade Math Curriculum (Defined as the Common Core State Standards for Mathematics)?*

Categories	Subcategories	Total (n = 27)
Pedagogical content knowledge	Knowledge of content and students	18.52%
	Knowledge of content and teaching	18.52%
	Knowledge of content and curriculum	74.07%
Dispositions	Confidence	29.63%
	Eagerness	11.11%
Activities	Interactions	18.52%
	Classroom	18.52%

Tables 21 and 22 summarize the participant data for Question 2, “What impact has your new knowledge had on your teaching? Table 21 lists the overall categories addressed by each group of participants, along with the percentage of each group of participants that addressed each category, combined and individually. Table 22 includes



the subcategories that were addressed by each group of participants, including the percentage of participants addressing each subcategory.

Table 21

*Responses to Question 2 by Category: What Impact Has Your New Knowledge Had on Your Teaching?*

Categories	Total ( $n = 27$ )
Pedagogical content knowledge	81.48%
Dispositions	29.63%
Activities	29.63%

Table 22

*Responses to Question 2 by Subcategory: What Impact Has Your New Knowledge Had on Your Teaching?*

Categories	Subcategories	Total ( $n = 27$ )
Pedagogical content knowledge	Knowledge of content and students	0.00%
	Knowledge of content and teaching	74.07%
	Knowledge of content and curriculum	18.52%
Dispositions	Confidence	7.41%
	Eagerness	7.41%
	Overwhelmed	3.70%
Activities	Interactions	0.00%
	Classroom	29.63%

Tables 23 and 24 summarize the participant data for Question 3. Table 23 lists the overall categories addressed by each group of participants, along with the percentage of each group of participants that addressed each category, combined and individually.

Table 25 includes the subcategories that were addressed by each group of participants, including the percentage of participants addressing each subcategory.

Note that in Table 23, the SMP appear as a separate category. However, when themes for the overall data set were established, this category was grouped with MKT, indicating that knowledge of these mathematical practices is part of the theme MKT, though it is not contained in the framework developed by Ball et al. (2008).

Table 23

*Responses to Question 3 by Category: What Impact Has Your New Knowledge Had on Student Learning in Your Classroom?*

Categories	Total ( <i>n</i> = 27)
Pedagogical content knowledge	62.96%
Dispositions	37.04%
Standards for mathematical practice	66.67%

Table 24

*Responses to Question 3 by Subcategory: What Impact Has Your New Knowledge Had on Student Learning in Your Classroom?*

Categories	Subcategories	Total ( <i>n</i> = 27)
Pedagogical content knowledge	Knowledge of content and students	29.63%
	Knowledge of content and teaching	37.04%
	Knowledge of content and curriculum	0.00%
Dispositions	Confidence	3.70%
	Eagerness	0.00%
	Overwhelmed	0.00%
	Student dispositions	37.04%
Standards for mathematical practice	MP1: Problem solving	22.22%
	MP2: Reasoning	18.52%
	MP3: Explaining	48.15%
	MP4: Modeling with mathematics	0.00%
	MP5: Using tools strategically	0.00%
	MP6: Using precision	3.70%
	MP7: Generalizing	0.00%
	MP8: Using repeated reasoning	0.00%

Tables 25 and 26 summarize the participant data for Question 4. Table 25 lists the overall categories addressed by each group of participants, along with the percentage of each group of participants that addressed each category, combined and individually. Table 26 includes the subcategories that were addressed by each group of participants, including the percentage of participants addressing each subcategory.

The quantification of this data set allowed me to identify the categories teachers perceived as having the strongest impact of the treatment. Although many references to subject matter knowledge and to pedagogical content knowledge existed, I noted the number of times participants mentioned their own increase in confidence and eagerness

to attempt new strategies. The questions specifically addressed participants' knowledge and application, yet several of them addressed levels of confidence in themselves and their students as noteworthy.

Table 25

*Responses to Question 4 by Category: Using the Mathematical Knowledge for Teaching Diagram, Explain How Your Knowledge of Teaching Math Has Changed as a Result of Participating in This Class.*

Categories	Total (n = 23)
Subject matter knowledge	26.09%
Pedagogical knowledge for teaching	65.22%
Mathematical knowledge for teaching (general)	34.78%

Table 26

*Responses to Question 4 by Subcategory: Using the Mathematical Knowledge for Teaching Diagram, Explain How Your Knowledge of Teaching Math Has Changed as a Result of Participating in This Class.*

Categories	Subcategories	Total (n = 23)
Subject matter knowledge	Common content knowledge	4.35%
	Specialized content knowledge	4.35%
	Horizon content knowledge	17.39%
Pedagogical content knowledge	Knowledge of content and students	39.13%
	Knowledge of content and teaching	30.43%
	Knowledge of content and curriculum	39.13%
Mathematical content knowledge	General	34.78%

### Field Notes

The field notes were analyzed using the sequential-analysis method (Miles & Huberman, 1994). Table 27 indicates the number of data segments that remained after the process described in Chapter 3 was complete. Upon examination of the categorized data segments, generalizations began to emerge. Those generalizations appear following Table 27.

Table 27  
*Field Note Segments Relevant to Research Questions*

	Professional development	Participant learning	Classroom practice	Student learning	Related concerns
Dispositions	16	18	7	7	
District support	2	2	2		25
Evidence of learning		6			
General content knowledge		4			
Horizon content knowledge		2		3	
Knowledge of content and curriculum		12	1	2	
Knowledge of content and students	2	7	10	20	
Knowledge of content and teaching	15	3	15		
Logistics	2				
Mathematical practices	1	7	19	1	
Specialized content knowledge	6	2	3		
Workshop activities	17	6	4		
Totals	62	69	62	30	25

**Professional development.** Looking at the column titled *Professional Development Activities*, the codes most frequently represented included dispositions, KCT, and workshop activities. In disposition, comments centered on high-engagement levels and rapport building between participants and their peers, as well as with the presenter. The teachers frequently verbalized their ideas regarding connections between various learning activities as well as with the course content and other district initiatives such as the Boys Town management system. As for workshop activities, several participants claimed that examining student work provided the greatest benefit to their understanding of how to implement the CCSSM in their classrooms. The most repeated comments centered on activities in which mathematical practices were discussed and applied.

**Participant learning.** The two most frequently occurring categories in participant learning focused on dispositions and KCC. Statements were made regarding how this class “broke down the content standards and helped us understand them and what we’re

suppose to teach at our grade level. The common core was brought down to our level so we can understand it.” Furthermore, many participants noted that although they had received exposure to the mathematical practices in the past, this was the first time they understood them. Additionally, I noted that over the course of time, participants became increasingly accurate in their descriptions of the mathematical practices and their conceptions of classroom implementation. The way they engaged with the content standards and mathematical practices transformed how they think about mathematics. I noted that the group was interested, eager, and engaged while interacting with the content standards. As with the participant reflections, the data revealed a convergence between gains in intellectual knowledge and the way participants felt regarding the impact of that knowledge.

**Classroom practice.** In the context of classroom practice, the data from the field notes most frequently centered on KCT and mathematical practices. In the context of classroom practice, the field notes data revealed several connections identified by participants. These included connections between mathematics concepts such as place value and operations; connections between mathematics and other instructional areas such as language-arts strategies, lesson-plan design, and objective selection; and connections between mathematics instruction and general classroom-management principles. Furthermore, mathematical practices received strong emphasis in this cluster. Teachers commented that the practices were especially effective as struggling students became more proficient over time at explaining their reasoning using words, charts, pictures, and numbers. The data included statements such as, “Struggling students came up with unexpected strategies and participated at levels they could not before.” Teachers

also commented on refining their own efforts in eliciting student responses and in guiding students to discover more efficient models for demonstrating their solutions.

**Student learning.** Regarding student learning, evidence points to teachers' frequent discoveries of how much students are capable of, as well as surprises over misconceptions regarding foundational concepts such as place value. One teacher commented on the way students were able to produce mathematics and understand things the teacher never thought possible. By using transitional strategies and problem types, teachers noted that their students became increasingly adept at using alternative computation strategies while also noting how much their students struggle with different types of problems such as change and start-unknown contexts.

For example, in preparation for Session 4, participants administered three versions of the same word problem to their students on 3 subsequent days. On the first day, the word problem had the "result" unknown (e.g., Mary had 42 eggs and Saul gave her 39 more. How many did Mary have then?). On the second day, the word problem had an unknown "change" number (e.g., Mary had 42 eggs and Saul gave her some more. If she had 81 eggs altogether, how many did Saul give her?). And on the third day, the word problem had an unknown "start" number (e.g., Mary had some eggs and Saul gave her 39 more. How many did Mary have to begin with?). The teachers found that their students had very little trouble with the result-unknown problem, moderate difficulty with the change-unknown problem, and significant difficulty with the start-unknown problem. The teachers were shocked, given that the context and numbers were identical from one day to the next. This led to animated conversations among the teachers about what their

students needed to learn and what they, themselves needed to do to prepare themselves to teach more effectively.

**District support.** Although no direct measures of organizational support were developed for this study, several data points indicated a high degree of frustration regarding the district's translation of the CCSSM through assessments and pacing guides. For examples the district assessment was aligned with the old state standards rather than the CCSSM. Due to this lack of alignment, teachers felt a great deal of pressure from their school principals to keep up with the district assessment, not allowing them the time needed to fully implement each standard in the CCSSM. In addition, the district pacing guides were out of sequence in place value and operations. When I took this issue to district administrators, they were grateful and indicated that they would make changes to the pacing guide for the following year, indicating their willingness to adapt their in-district translations to embrace the CCSSM more fully. Interestingly, these teachers commented that they thought the district pacing guides *were* the actual CCSSM documents and were surprise to learn otherwise. From a different perspective, district and school administrators frequently commented that they were witnessing dramatic, positive changes in classroom instruction.

### **Summary**

Taken together, the results revealed that the treatment had a positive impact on participant learning in both groups, as indicated by the LMT and the online sorting task; a mild effect on the experimental group's instructional practice, as compared to the untreated comparison group, as indicated by the observations and interviews; and no discernable difference on student learning, as detected by the Galileo student assessment.

The analyses of the participant reflections and field notes provided additional anecdotal evidence that teachers' knowledge, skills, and dispositions were positively impacted by the treatment.



## CHAPTER 5

### DISCUSSION

In an effort to design effective professional development leading to implementation of the CCSSM, this study aimed to answer the following questions:

1. What is the relationship between professional development for the CCSSM and teacher knowledge, skills, and dispositions?
2. What is the relationship between professional development for the CCSSM and classroom practice?
3. What is the relationship between professional development for the CCSSM and student learning?

To address Question 1, the results presented in Chapter 4 revealed that the professional development treatment had a positive impact on teachers' MKT as revealed by the statistically significant LMT gain scores for the experimental group and for the follow-up with the control group. Furthermore, teachers' knowledge of the standards was also impacted by the treatment, as indicated by the *t*-test results for the online sorting-task scores for both groups, indicating that although the control group gained in their knowledge of the standards slightly during the first treatment, there was a statistical difference between the treatment and control groups during the treatment. In addition, after both groups had received the treatment, their net growth in knowledge of the standards was almost identical, as revealed by the lack of statistical difference in their final posttest scores.

To address Question 2, four teachers from the experimental group and their matched-pair partners participated in observations and interviews to discern differences

in their instructional practice during the initial treatment. An analysis of the RTOP results showed that there was a statistical difference between the two groups, although the results are not generalizable due to the small sample size. Furthermore, an analysis of the interview data also revealed a difference in their perceptions of their teaching, with the teachers from the experimental group exhibiting a greater awareness of practices that are described in the MKT literature as well as represented in the CCSSM's SMP. Given that the observations and interviews took place during Months 2 and 3 of the initial treatment, a longer duration of time may have allowed for deeper integration and refinement of skill to reveal a more distinct difference between the two groups.

To address Question 3, an analysis of student-achievement data from the Galileo student assessments revealed that no statistically significant difference existed between the two groups. Therefore, the impact of the treatment on student learning was inconclusive. The results from the student assessments, although not statistically significant, yielded a slight differences in the class means after the first treatment, and that difference diminished after the follow-up treatment. This result warrants further attention due to the low power produced by the small number of participants, as well as the short duration in time that passed between each pre- and posttest.

To further address all three questions, I conducted an analysis of participant reflections and field notes to provide anecdotal evidence that the treatment impacted the participants' MKT, classroom practice, and student learning. These results provided insights into the participants' perceptions of their learning and its impact on instruction and student learning, as well as into the structure and impact of the treatment.

Taken together, these results indicate that the treatment's strongest impact was on teacher knowledge, with a smaller impact on classroom practice, and virtually no impact on student learning. According to the theoretical framework from the literature (Desimone, 2009, Figure 4), professional development such as that designed for this study is directly connected to teacher knowledge. Teacher knowledge is a mediating variable between professional development and classroom instruction, and both teacher knowledge and classroom instruction are mediating variables for student learning. It follows that the professional development treatment in this study was directly linked to teacher knowledge but yielded only indirect contact with the classrooms and students.

That said, the beauty of a mixed-methods study exists in the cross examination of qualitative data used to verify, enhance, and invigorate the numerical data. For the purpose of this study, qualitative analyses were conducted on my field notes as well as on participants' reflections, in addition to the interview data, and these results will be woven into the discussion that follows. The discussion addresses the theory of change, divided into five areas: context, professional development design, teacher knowledge, classroom instruction, and student learning, returning to the theory of change introduced in Chapter 1. Because the theory of change begins with the general context and professional development design, those sections appear first. Although they were not directly assessed in this study, the context and treatment were addressed in the qualitative analyses and lay the foundation for the data discussion that follows.

## Inputs: Context and Professional development Design

### District Context as a Mediating Variable

Although the focus of this study concentrated on the impact of CCSSM professional development on teacher knowledge, classroom practice, and student learning, the context in which the professional development took place emerged as a mediating variable. Well documented in the literature, the organizational support from the district, types of assessment, availability of resources, and presage factors such as teacher experience and student prior learning, impact the implementation of new standards (Desimone, 2009; Hill, 2001; Spillane, 2004). In the context of this study, evidence of such impact emerged from the both the quantitative and qualitative analyses.

Figure 11, illustrates the context variables from the theory of change that appears in Chapter 1.

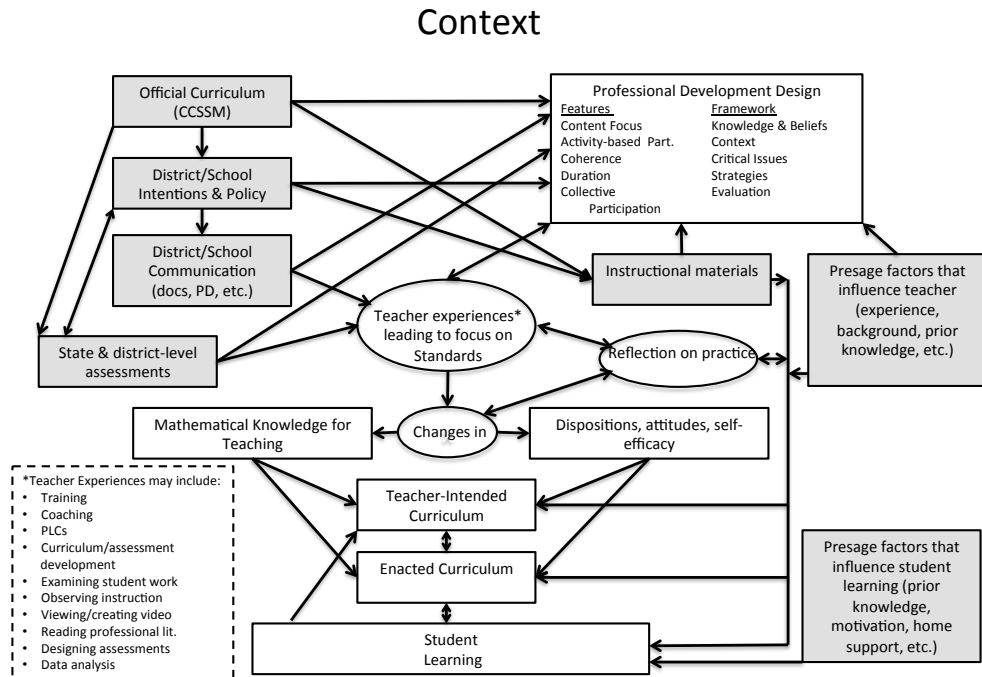


Figure 11. Theory of change—Contextual features shaded.

**Organizational support.** The online sorting task in which teachers participated provided evidence that contextual factors such as organizational support and availability of resources promoted positive growth in participants' knowledge outside the realm of the CCSSM professional development under study. Although the experimental group made significantly greater gains than the control group during this time frame, as shown by the sorting-task analysis, measureable growth in knowledge of the content of the standards was detected by this measure, as well (net growth was 7.22 and 3.38, respectively). Further investigation with district administrators revealed that all teachers, experimental and control, participated in district-level meetings focused on the CCSSM during the same time frame of the treatment, thereby adding to the knowledge base of both groups. Interestingly, but the end of the follow-up treatment, the growth scores were almost identical for the two groups, further substantiating that the treatment's effect was significant, even in the midst of other interventions taking place in the district context.

In addition, analyses of the field notes and participant reflections revealed that teachers attended to the district curriculum map and assessment guides while participating in this CCSSM course, attempting to integrate their new learning with the resources at hand. For example, participants frequently brought the district curriculum map with them, comparing and contrasting the map with the CCSSM document. Teachers commonly observed that although the district curriculum map was divided into manageable chunks of content, the large number of pages (23 pages in all) distracted them from seeing the connections between domains and across grade levels that were much easier to detect in the CCSSM document itself. Furthermore, teachers commented that the interpretation provided by the district did not appear to clearly translate the

meaning of the common core, a phenomenon uncovered in other studies (Hill, 2001; Spillane, 2004). Teachers also increasingly became astute at identifying the lack of cohesion between the content standards and the SMP in the context of their district framework, leading to frustration, followed by deep conversations aimed at unraveling the perceived inconsistencies between the district and the Common Core documents.

Observations such as these led to frequent conversations between the consultant and the district and school administrators, with the goal of smoothing over perceived differences in the delivered messages in the CCSSM professional development and in the other communication and resources provided by the district regarding implementation of the CCSSM. This frequent disconnect between professional development and communication efforts also frequently appears in the literature, leading to the need for coherence within and between reform efforts in districts (Borko, 2004; Chval, 2008; Darling-Hammond et al., 2009; Desimone, 2009).

**Assessments.** Studies have shown that teachers pay attention to the district materials and district and state assessments as primary indicators of what the official curriculum includes (Cohen & Hill, 2000; Confrey, 2007; Spillane, 2004). Participant reflections and field notes validated this by revealing that during the initial and the follow-up treatments, teachers frequently brought in their district Galileo assessments and results, unsolicited, expressing frustration at the disconnect between the CCSSM, which they were supposed to teach, and the content in the district assessments. The purpose of these assessments was to predict student readiness for the state assessments to be given at the end of the school year.

The main distinction, leading to tremendous teacher frustration, centered on the notion that the assessments were aligned to the former state standards and the district-mandated curriculum was focused on the CCSSM. The use of these assessments to discern whether individual students had mastered classroom content functioned as a hindrance to full implementation of the CCSSM, according to the teachers. They commented on the pressure their school principals placed on them for better test results, when several of the items (11 of 43 on one form) did not appear in the CCSSM. Interestingly, and supporting the work of other researchers, the teachers were unaware of the disconnect between the district assessment and the CCSSM prior to the treatment because they paid complete attention to their district mechanisms rather than the state-mandated policies, in this case the CCSSM (Hill, 2001; Spillane, 2004).

**Instructional resources.** Knowing that instructional resources often play an important role in professional learning opportunities (Cohen & Hill, 2000; Confrey, 2007; Spillane, 2004), an effort was made to connect the district-level resources available to teachers with the CCSSM training in this study. Analysis of the field notes and participant reflections revealed that teachers sense a strong lack of availability from their district. During the observations and interviews, teachers commented that they did not have a cohesive set of support materials, nor did they have a district-adopted text. This was confirmed through conversations with the district administration. During the time of this study, the district was collecting online resources for teaching the common core standards for mathematics and posting them to the district website for teachers to access.

The lack of consistency between instructional materials gathered from multiple sources and the varied abilities of teachers to weave them together into cohesive units of

study was noted by the teachers and administrators alike. As a result of the lack of CCSSM resources provided by the district, many study participants noted that the exemplar lessons and activities shared during the CCSSM course provided much-needed classroom resources for them to use in their classrooms.

In sum, this discussion regarding organizational support, instructional materials, and student assessments, provides background to the impact of the CCSSM professional development on teachers, instruction, and learning. These three factors have a profound impact on teachers' opportunity to learn and the likelihood for application. As in this study, addressing each of these in the context of teacher development may play a critical role toward maximizing the impact of professional development. Further study of these factors, both individually and in unison, is warranted.

### **Professional Development as the Focus of Study**

Both context and professional development design played integral roles for impacting the variables examined in this study. Taking into account theories for MKT (Ball et al., 2008), the importance of activity-based learning (Desimone, 2009; Ferrini-Mundy et al., 2007), and participant interactions (Borko, 2004; Loucks-Horsley et al., 2010), the experiences in this CCSSM course were carefully designed and sequenced to promote not only basic recall of grade-level CCSSM, but also a deeper understanding of how those standards might look in the classroom context. (See Chapter 3 for a description of the treatment design and Appendix C for an overview of the activities used.) Although these characteristics were not examined individually, they were incorporated into the treatment design for this study, validated by the field notes and participant reflections. In Figure 12, the sections that address the professional development design include the



descriptors from professional development frameworks (Borko, 2004; Desimone, 2009), professional development design features (Loucks-Horsley et al., 2010), reflections, and experiences. Although not directly part of the current study, instructional materials are also included as part of the professional development design as well, because they provide an additional source to potentially impact MKT, and therefore classroom instruction.

### Professional Development Design

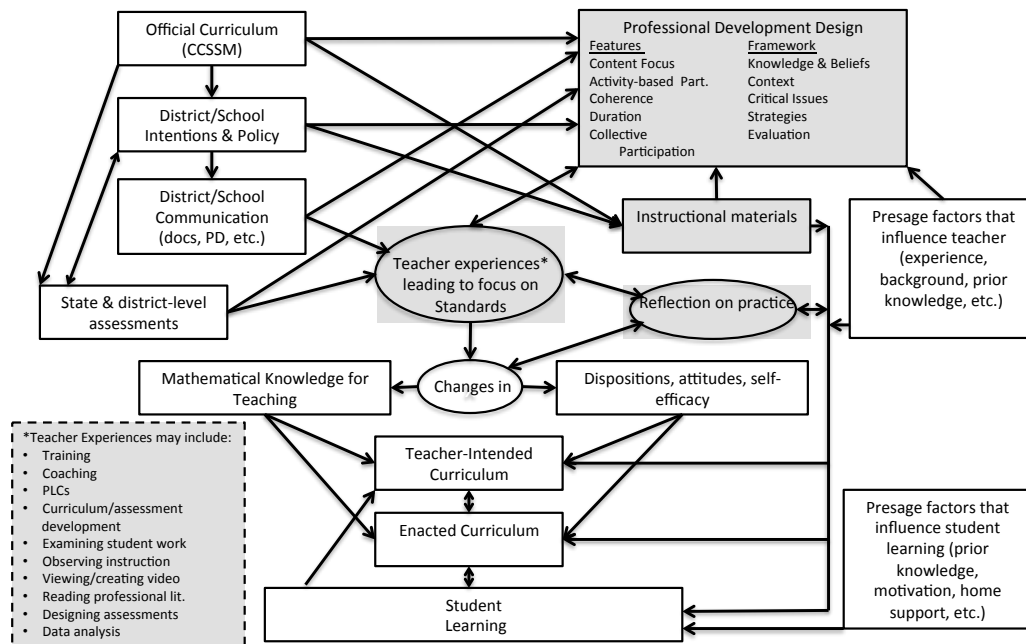


Figure 12. Theory of change—Professional development features.

In the field notes and participant reflections, participants provided evidence of the benefits of experiencing strategies for common core implementation. They talked about how this class was changing the way they teach, that teaching “this way” was more fun, and that the workshop activities, transferred to the classroom, were bringing the common

core to life. Over the course of time, participants began to create their own activities, linked to the CCSSM, and eagerly brought them to class to share with the group.

The importance of carefully selecting and sequencing teacher experiences in this type of professional learning directly impacts the teachers and their thinking, but only indirectly impacts classroom implementation and student learning (Borko, 2004; Desimone, 2009; Desimone et al., 2002). Assisting participants to envision how to embed the content and practices of the CCSSM may lead to greater fidelity to the standards within the context of classroom practice, so that students can achieve the standards. Therefore, during this study, participants engaged in experiences such as examining student work, observing video footage of classroom instruction, reading professional literature, discussing and debating the issues of classroom management, analyzing student data, and participating in simulations. Once again, the teachers' responses, as evidenced in the reflections and field notes, indicated that such experiences led to greater levels of confidence and enthusiasm, both for them and for their students.

### **The Relationship Between CCSSM Professional Development and Teacher Knowledge**

Because this study was primarily centered on the impact of professional learning experiences on teacher knowledge, the major findings focus on differences in subject-area knowledge and pedagogical content knowledge, with an emphasis on knowledge of the official curriculum, as defined by the CCSSM. However, evidence also emerged in the qualitative data that pointed to shifts in teachers' dispositions, attitudes, and self-efficacy, noted in the interviews, reflections, and field notes. The conversation that follows weaves together a discussion regarding these areas, illustrated in Figure 13.

## Impact on Teacher Knowledge

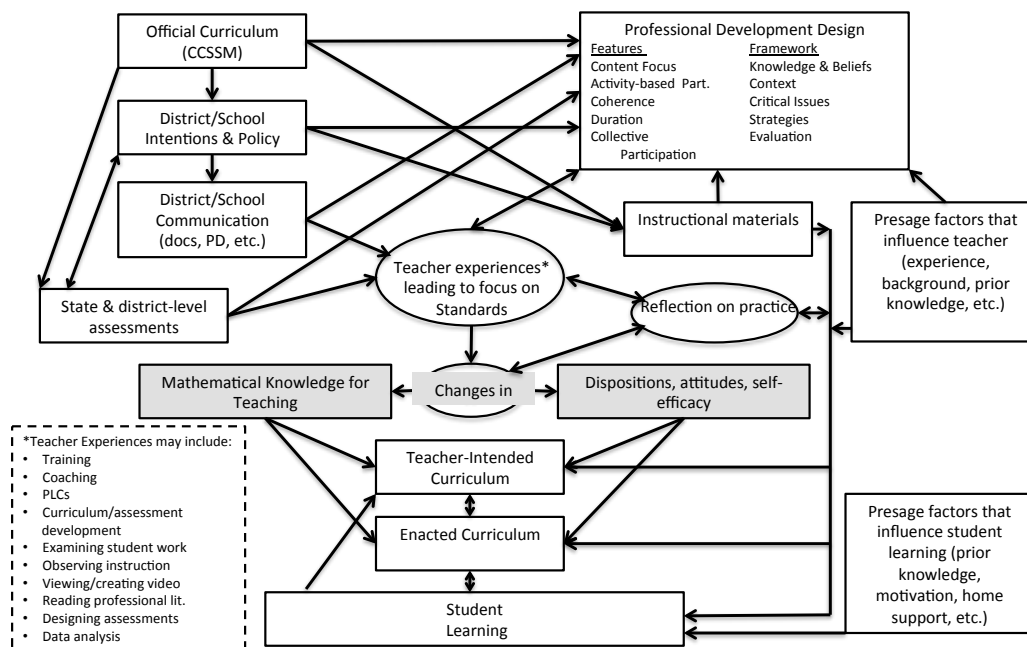


Figure 13. Theory of change—Impact on changes in teacher knowledge.

### Teachers’ Knowledge of the Curriculum

The primary intention of the CCSSM course designed for this study was to increase teachers’ awareness and deep understanding of the content and pedagogy promoted in the common core standards. The results of the online sorting task revealed that significant growth in their knowledge of the content standards occurred during this course, above and beyond the other outside opportunities provided by the district. The analysis of the LMT scales revealed that content knowledge also increased during the course. In addition, teachers frequently testified that their knowledge of the content standards and of the mathematical practices were making an impact in their classrooms. For example, teachers noted that they had trouble shifting away from teaching the standard algorithms for addition and subtraction, replacing them with strategies based on

place value and relationships between the operations. They also noted that they never before understood that teaching fractions in second grade could be so complex.

Also noteworthy was the number of times teachers mentioned their struggles and their experimentation with the SMP. During the later sessions in the course, the teachers spoke increasingly about practices such as asking questions rather than “showing,” providing opportunities for students to explain their reasoning and defend their answers, and urging students to self-correct their work. They also discussed the need for teachers, themselves, to have a stronger command of mathematical vocabulary. By way of contrast, teachers confided that other training sessions they had attended afforded them opportunities to interact with the SMP, but without any explanation or understanding of what each meant. During their interactions in this course, they were able to better grasp the implications of these practices over time. One participant even mentioned that in the beginning, this teacher did not see why it was necessary to insist students take the time to explain their reasoning, but after taking this course, the teacher was better able to explain how mathematics worked, personally, and was better equipped to have the students explain their thinking, as well.

This result leads to the conjecture that when teachers neglect to see the need for implementing new strategies and techniques, perhaps the issue, at least in part, resides in their own misconceptions and lack of understanding. Even with the many success stories that unfolded throughout the course, some participants still confided that although they were excited about these new ways of teaching and learning, they continued to struggle with implementation. The field notes reveal that teachers’ understanding of the standards, especially the mathematical practices, was still evolving. Continued work was needed to

help them further their understanding, providing more time and opportunity for them to develop their knowledge and embed their new understandings in classroom practice.

### **Teachers' Content Knowledge**

Perhaps one of the most interesting phenomena that took place during this CCSSM course revealed itself in the growth of teachers' content-area knowledge as a result of the professional learning opportunities. The LMT was designed to detect differences in teachers' knowledge, primarily in the areas of SCK, KCS, and KCT (Hill, 2007a). Although the CCSSM course was designed to primarily impact KCC, a significant difference in LMT scores existed between the experimental and control groups. This appears to indicate that although the focus was on curriculum, something in the professional learning experiences also impacted teacher content knowledge of the K–6 mathematics curriculum. Even more interesting was that the treatment focused on the content to be taught in second grade, yet the LMT is designed to cover content in kindergarten through sixth grade, once again indicating that the experiences in this CCSSM course offered more than just an understanding of the second-grade curriculum. It also had an impact on understanding the teaching and learning of mathematics across all elementary grades.

Two purposeful design features in the course included a focus on horizon knowledge and an ongoing emphasis on the practices and dispositions of mathematics learning. In the case of horizon knowledge, teachers were frequently encouraged to consider connections of the second-grade content across other grade levels. For example, the teaching of halves, thirds, and fourths in the context of decomposing geometric

figures, has implications for the notions of equivalence and mixed numbers in future grade levels.

Perhaps even more significant than the integration of HCK was the focus on the mathematical practices themselves. As teachers were learning about how to help their students think deeply about the mathematics they learn, teachers were concurrently thinking deeply about the mathematics they teach. The teachers were engaging in problem-solving tasks, anticipating how students might respond to various prompts and materials, predicting various models and tools students may use to find solutions, and discussing the arguments students might offer in place of simply providing answers. Teachers were being driven to think in new ways, sometimes experiencing the disequilibrium that new learning brings, much as their students experience in the classroom. Perhaps these experiences with HCK, and in anticipating the use of the SMP impacted the way teachers interacted with the LMT items. Further investigation is warranted to tease out the cause.

### **Teachers' Dispositions**

In addition to evidence of differences in the participants' MKT, another intriguing trend occurred regarding participant dispositions. When asked to reflect on the impact this course had on their knowledge of the common core standards for their grade level, several participants commented on notions such as eagerness to try new strategies, increased confidence in their teaching, and increased enjoyment of teaching. They were asked to comment on their knowledge, and they discussed their dispositions. The learning process includes such dispositions as eagerness, confidence, frustration, and disequilibrium (Spillane, 2004). Even resistance to change, which was overtly addressed

by one participant, is part of the change process inherent when deep learning occurs. In the context of this study, many of the new understandings of the content standards and mathematical practices were accompanied by statements of both positive and negative dispositions and attitudes. For example, one participant who claimed to have had an overwhelmingly positive experience in this course was in tears during the third session because she could not figure out what these new standards should look like. Once she had the chance to view an instructional coach in action and try it on her own for a couple of months, her conception of success had reversed.

### **The Relationship Between CCSSM Professional Development and Classroom Implementation**

As mentioned previously, classroom implementation and student learning are only indirectly impacted by professional learning experiences such as those offered in this study (Borko, 2004; Desimone, 2009; Desimone et al., 2002). Although this study aimed to connect professional development and classroom implementation, the mediating factors that exist between these two are those of teacher conception and MKT.

Professional learning experiences directly impact teacher knowledge, and then, in turn, changes in teacher knowledge make their way into the classroom (Desimone, 2009).

That said, one would be neglectful to not examine the impact on instruction because, after all, the goals of teacher development come to fruition when changes in classroom practice emerge. Figure 14 highlights this principle—that changes in teacher knowledge, including dispositions, attitudes, and self-efficacy, must be translated into classroom practice (teacher-intended curriculum and enacted curriculum) for differences in student learning to be perceived.

## Impact on Classroom Instruction

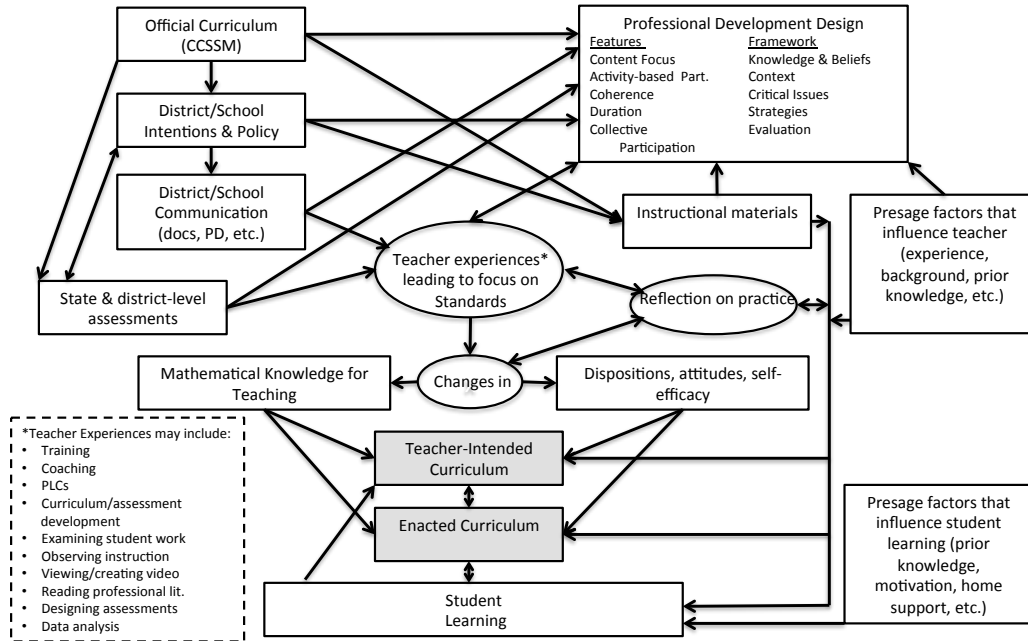


Figure 14. Theory of change—Impact on classroom practice.

Throughout the course of this study, participants interacted with several learning experiences such as planning lessons, anticipating student responses, interpreting students’ emerging thinking, and understanding common student errors. Through these experiences, connections to classroom implementation were strengthened. In addition, direct classroom observations provided the opportunity to look directly at differences between experimental and control teachers’ attempts at teaching the CCSSM, keeping in mind that concurrent CCSSM training was being conducted for all teachers by leaders in the school district.

### Evidence in the Professional development Setting

**Planning.** Teachers who spend time coplanning their lessons, including the integration of new content and pedagogy, find greater success during the enactment of the



plans as well as with student learning. Collaborative planning has been widely recognized as a valuable professional development tool, as well (Loucks-Horsley et al., 2010; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). During this study, teachers appeared to be eager, enthusiastic, and communicative during the planning sessions, they used resources, such as the course binder activities, and textbooks to help them deepen their understanding of each CCSSM standard. In addition, they would bring in lesson plans and resources they had used in the past, adapting old plans to incorporate mathematical practices and the specific content standards for their grade level. Furthermore, they selected and wrote questions to ask for facilitating focused discourse, and they dissected their classroom-management techniques with the intention of making practices such as selecting tools strategically and modeling with mathematics more accessible to their students. In their reflections, participants referenced this collaborative time as an integral part of their connections between what they learned in the course and what they implemented in the classroom.

**Anticipating student responses.** Engagement in solving mathematics tasks with the intention of anticipating student responses provides another type of experience valuable in transferring knowledge to classroom practice (Ferrini-Mundy et al., 2007). These experiences allowed teachers to plan for how they would lead the students toward engagement in practices such as constructing arguments and critiquing the arguments of others. For example, teachers realized that changing the way they word a prompt could change the way students would engage with the practices. Also, anticipating the models and tools students tend to use, such as picture drawing, and thinking of ways to guide them toward more efficient strategies, such as diagrams with place-value representations

rather than single objects, helped teachers navigate their role as *facilitators of learning* rather than as *directors of activity* in their classrooms. Taking the time to simulate teacher–student interactions and playing games with the mindset of determining how to differentiate for various students provided participants with opportunities to bridge their emerging understanding of the standards with strategies for classroom implementation.

**Interpreting students’ emerging thinking.** Examining student work has also proven to be a useful professional development tool (Borko, 2004; Desimone, 2009; Ferrini-Mundy et al., 2007; Loucks-Horsley et al., 2010). Once teachers participated in simulations and discussions during the course, they went back to their classrooms to try new strategies and techniques and then brought student work back to class for analysis and discussion. This provided opportunities for them to see real examples of the common student errors discussed during class, as well as those encountered during professional reading. Participants were able to identify and provide solutions for issues such as the poor selection of tools and models such as drawing single objects to represent multi-digit arithmetic. They had opportunity to discuss common student errors, such as place-value errors when mentally adding 10 or 100 to a given number. And they encountered common student roadblocks such as the frustration students expressed when they went from the ease of solving result-unknown problems to the frustration of solving start-unknown problems, even when the context and numbers were exactly the same (Carpenter, Fennema, Franke, Levi, & Empson, 1999). In all of these cases, teachers were surprised at the difficulties students encountered and were afforded the opportunity to discuss what happened and receive support in devising possible solutions to try before the next class meeting.

## **Evidence Gleaned from Classroom Observations**

The differences observed between experimental and control teachers in the context of classroom observations also sheds light on how carefully designed professional learning experiences can impact classroom practice. First of all, an analysis of the RTOP results revealed a statistical difference in classroom practices between treatment teachers and their matched pairs. Furthermore, an analysis of the responses to the interview questions regarding the decisions made in each lesson revealed that teachers in the experimental group perceived their actions through a lens that reflected the intentions of the MKT descriptors in contrast to that of their counterparts. Teachers in the experimental group were more likely to encourage strategies besides the standard algorithm, to focus on patterns and number relationships rather than rote arithmetic, to focus on student thinking about problem types rather than demonstrating how to solve word problems, and to use questions to guide thinking rather than resort to direct demonstration. Furthermore the descriptions mentioned above directly reflect the topics and conversations that took place during the CCSSM professional development. It appears that even though the professional development setting indirectly impacts classroom practice, carefully planned interactions can lead to changes in classroom practice.

As seen in the RTOP results, a discernable difference between the teachers in the experimental and control groups appeared during the analysis, with the exception of the first pair, where there was a difference in RTOP scores, but not in the interview analysis. Overall the treatment group revealed a higher percentage of providing examples of making decisions that corresponded with MKT indicators than the control group (79%

and 47%, respectively). The most frequent examples in line with MKT indicators that emerged from interviews included (a) interpreting students' emerging and incomplete thinking, (b) evaluating the instructional advantages of representations, and (c) assessing whether a nonstandard approach would work in general. For the control teachers, the only positive examples of MKT indicators that appeared more than once was deciding when to ask for more clarification.

Although these interviews neglected to provide opportunities for teachers to reflect on the how the professional development treatment was impacting their classroom practice and decision making, one of the treatment teachers responded with the following statement during the second interview: "Activity examples from the CCSSM class made me more comfortable. *This* is what I am supposed to be doing. *This* works for *this* standard. It's nice to have support of someone who's an expert in this." A recommendation for future research is to include a prompt that asks participants in the experimental group to reflect on possible connections between their instructional decisions and the professional development program. This was deliberately excluded for the current study, as I was not informed ahead of time which participants were in which group. However, the benefit of asking teachers to directly reflect on the relationship between the professional development and their classroom practice may outweigh the benefit of withholding group assignment from the observer.

### **The Relationship Between CCSSM Professional Development and Student Learning**

Finally, the ultimate goal of CCSSM professional learning efforts encompasses using effective teaching techniques and strategies resulting in changes in student learning of mathematics content, as well as student engagement in the SMP. However, just as with

classroom practice, the impact of professional learning experiences on student learning is indirect, with both teacher knowledge and classroom practice acting as mediating variables. Figure 15 draws attention to student learning as the final destination for all the policies, communication, experiences, and changes involved in this theory of change.

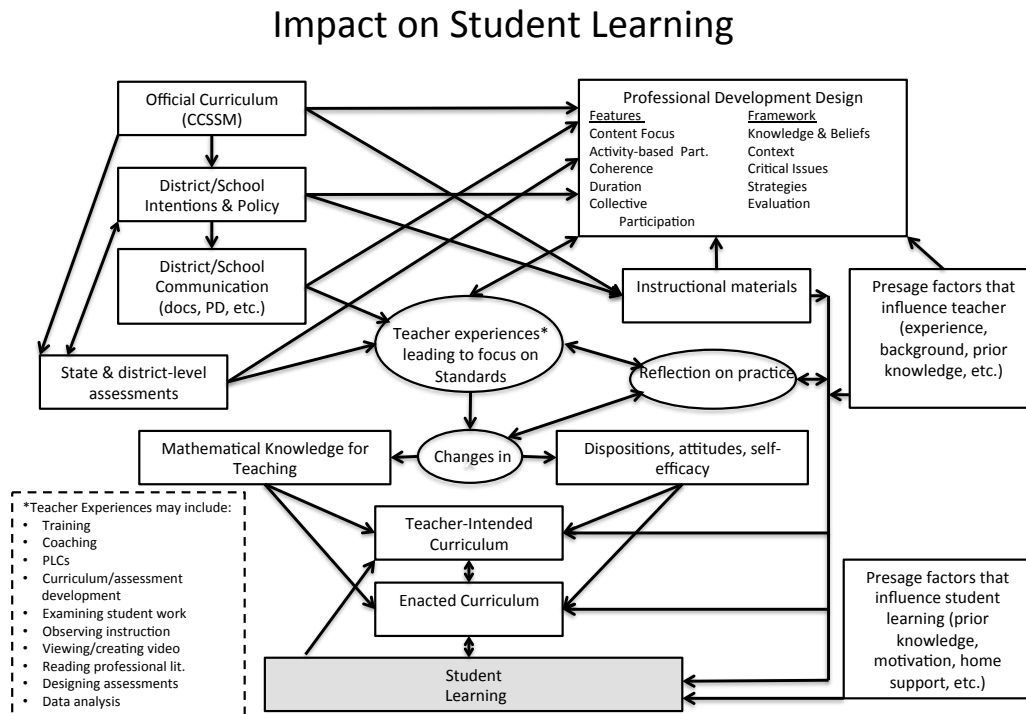


Figure 15. Theory of change—Impact on student learning.

As is common in the professional development literature, student learning indicators in this study did not reveal a statistically significant difference between the classes of experimental and control teachers. Although there was an arithmetic difference between the pre–post gains of the experimental and control groups, the high probability did not allow for the ruling out of chance. This may have been a function of the assessment itself, given that it was aligned to the old state standards rather than the CCSSM. Alternatively, and more likely, this may have been the result of the study having

little statistical power, given that only 37 participants, 18 treatment and 19 control, were involved in this part of the study. A third possibility is that the duration of each CCSSM course was only 4 months, providing time for teacher learning and classroom experimentation to occur, but perhaps not enough time to detect an impact on student learning. Regardless of the cause, further study with a larger sample size is warranted to determine if the discernable difference was due to chance or if there really was a significant difference between the experimental and control groups.

That said, the data collected from the reflections and field notes did provide noteworthy shifts in student classroom performance, albeit through the conceptions of the teachers. Teachers noted that they observed changes in student learning, especially with the way students engaged with mathematical practices. Teachers made claims such as, “I never knew my students would be able to explain their thinking in such profound ways.” Teachers noted that students engaged in explaining their reasoning with much greater frequency. Teachers also noted that students began to discover content connections on their own, such as connections between place value and coin counting as well as geometry and fractions.

Additionally, teachers became more aware of the struggles their students faced, given the new practices that were being implemented. Specifically, their students often struggled in the problem-solving process, unsure as to which strategies to use and how to connect new tasks to previously solved problems. Although many teachers noted an increase in student explanations, some also noted the difficulties their students faced when trying to build coherent arguments about the mathematical processes they used to solve problems. They perceived that the struggles their students faced, at least in part,

were due to previous exposure to traditional methods for finding solutions, especially with “borrowing and carrying” for addition and subtraction, in contrast to using strategies based on place value, properties, and the relationship between addition and subtraction, as prescribed by the CCSSM.

Overall, teachers noted that shifts were taking place, and the that additional work was to be done on their parts, to refine their skills in embedding CCSSM-based content and practices into their work, as well as to provide opportunities for the students to think and engage in ways not required of them in the past.

### **Interactions Between Variables—Revisiting the Theory of Change**

This efficacy study intended to discern the impact of CCSSM professional development on teacher knowledge, classroom practice, and student learning. If the CCSSM is going to lead to major shifts in student learning, then major changes in teacher knowledge, skill, and disposition must take place (Cobb & Jackson, 2011; Porter et al., 2011). However, the level of support required for teachers to make such shifts has yet to be determined (Heck et al., 2011). Transformations in teachers’ knowledge of content and of pedagogy are necessitated by the increased rigor of the CCSSM content standards and mathematical practices. However, changes in teacher knowledge are not enough. There must be changes in classroom practice and student learning, as well (Schmidt & Houang, 2012).

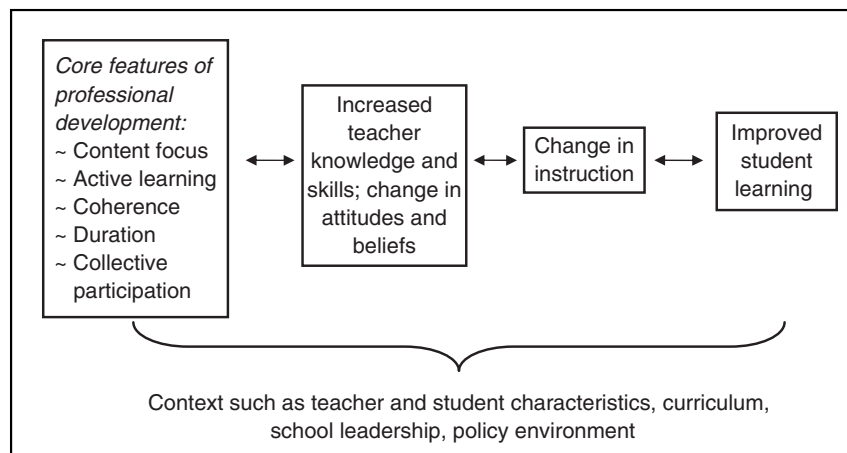
The relationship between professional development and classroom practice, absent of strategies such as instructional coaching, are indirect, decreasing the likelihood of seeing such an impact. However, by attending to Guskey’s (2000) five levels of evaluation, this study was able to triangulate data to discern differences in teacher

practice. By attending to teacher conceptions (reflections, field notes), changes in teacher knowledge (LMT, sorting task), organizational structure (field notes), and classroom implementation (observations, interviews), discernable impacts were detected. The conjecture here is that the types of exercises in which the teachers engaged made the difference. Activities such as examining student work, anticipating student responses, reflecting on classroom management, and direct interaction with the content and pedagogical implications of the CCSSM provided participants with opportunities to integrate the CCSSM into their already existing repertoire of teaching strategies. This often led to frustration, but the change process is a complex process (Spillane, 2004).

Similar to the relationship between professional development and classroom implementation, mediating factors also exist between the CCSSM course and student learning. The students are one more step removed from the impact of the teachers' learning experiences in that they are only impacted directly by the influences of classroom implementation, which is impacted by teacher knowledge, which is impacted by the initial teacher learning activities (Borko, 2004; Desimone, 2009; Desimone et al., 2002). In this study, student assessment data were examined, and although some promising results were observed, further examination is necessary to determine if these were, indeed, correlated to the professional development design. However, data collected from participant reflections, field notes, and observations did lend themselves to validating that student learning was impacted by the changes in classroom practice, resulting from the shifts in teacher knowledge due to the CCSSM professional development.



Although somewhat simplistic, Desimone’s (2009) proposed theoretical framework illustrating the impact of professional development provides a glimpse of the impact of the CCSSM professional development in this study. Figure 16 illustrates the relationships Desimone and colleagues wrote about for several years (Desimone, 2009; Desimone et al., 2002).



*Figure 16.* Theoretical framework for the impact of professional development.  
*Note.* From *Improving impact studies of teachers’ professional development: Toward better conceptualizations and measures*, by L. M. Desimone, 2009, *Educational Researcher*, 38, p. 185.

When compared with the theory of change designed for this study, a direct parallel can be seen. Figure 17 illustrates a simplified version of the theory of change emphasized throughout this chapter.

The overarching context of this study, as discussed previously, included the CCSSM documents, instructional resources, student assessments, organizational support, and teacher and student presage factors. The professional development opportunities include the features, framework, experiences, and reflection aspects of the design. The learning encounters directly impacted teacher knowledge, dispositions, and skills, as seen in several data sets, and these changes, in return, impacted the customization of the

professional development. As seen in the reflections, observations, and interviews, teacher knowledge impacted classroom practice, with a reciprocal relationship as teachers further refined their understanding while interacting with the students. And finally, the qualitative nature of this study facilitated detection of shifts in student interactions and learning, which provided feedback to teacher practice, knowledge, and professional development experiences. This simplified version of the theory of change encapsulates the professional development design and the study design, attending to all five levels of evaluation outlined by Guskey (2000).

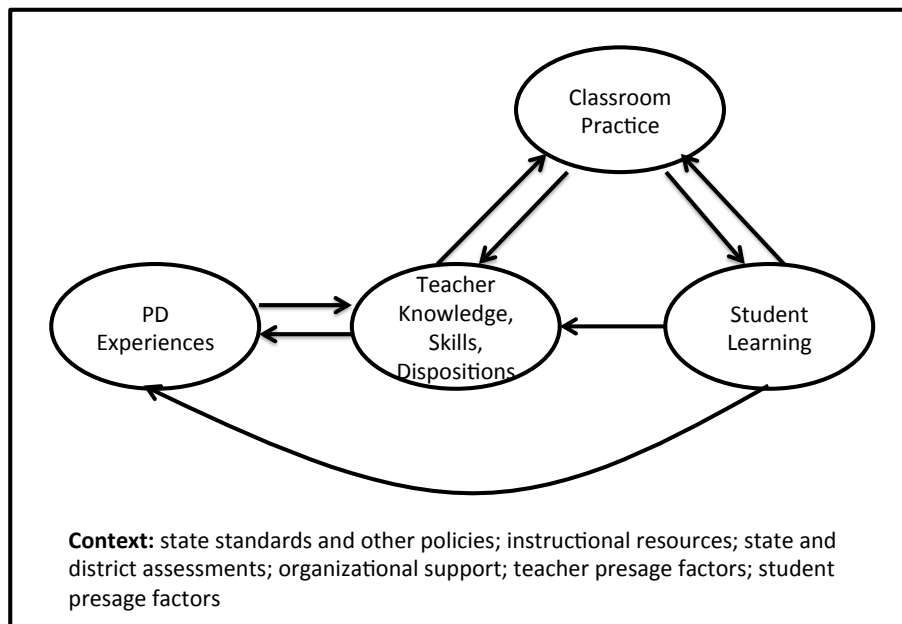


Figure 17. Simplified theory of change.

## Contributions, Implications, and Limitations

### Contributions

**Providing CCSSM implementation studies: Heck, Porter, Cobb.** This study originated, in part, with the release of the drafted *A Priority Research Agenda for*

*Understanding the Influence of the Common Core State Standards for Mathematics* (Heck et al., 2011). This report called for research of various aspects of the CCSSM, including studies focused on the efficacy of professional development that impacts teacher knowledge, skills, and dispositions. With the goal of creating and studying such a program, this current study contributes both a professional development model for the CCSSM as well as an efficacy study determining its impact on several different factors including teacher knowledge, classroom implementation, and student learning.

**Looking beyond knowledge of content and curriculum.** Although classroom practice and student learning were also examined, this study's strongest focus centered on the impact of the professional development model on participants' knowledge of the CCSSM. Using the sorting task as a tool designed to detect knowledge of the content standards specific to the teachers' grade level, statistical differences between the experimental and control groups were detected. However, the treatment was carefully crafted to not only increase participants' knowledge of the contents of their curriculum, but also to impact their MKT through interactions with the content as well as with colleagues (Ball et al., 2008; Borko, 2004; Hill & Ball, 2004). The use of the LMT, in conjunction with the sorting task and the participant reflections, allowed the discovery of knowledge beyond the basic CCSSM grade-level contents to have a much broader impact on their MKT across grade levels and deeper knowledge of how students learn. In essence, although this course was designed to focus on knowledge of curriculum, it also successfully impacted teachers' SCK, KCS, and KCT.

**Detecting “business as usual” impact.** The development of the sorting task led to an unanticipated result: detection of changes in knowledge of the curriculum in both

experimental and control groups, while concurrently finding a significant difference between the two groups. This detection acknowledged that when the “business” continued as usual throughout the study, namely, district-level learning opportunities and self-guided professional reading, growth in knowledge of the CCSSM took place in the control group, but at a slower rate. This phenomenon would be expected, but finding a way to substantiate it using a study-specific tool was a pleasant surprise.

### **Implications for Future Study**

**Organizational Support.** This study, in its current form, examined the relationship between a specific CCSSM professional development program on teachers’ knowledge, classroom practice, and student learning. The results reveal a promising model that appears to have had a marked impact, but the broader literature addresses the need for such programs to be situated in the broader system in which teachers work, namely district support offered by administrators, assessments, written materials, and culture (Desimone, 2009; Guskey, 2000; Heck et al., 2011; Hill, 2001; Loucks-Horsley et al., 2010; Spillane, 2004). Additionally, presage factors such as teacher experience and student backgrounds also factor into the success of standards-based teaching.

**Professional Development Strategies.** Because the professional development model for this study incorporated several strategies found successful for teacher learning, it focused on a whole system rather than pinpointing the level of impact of the specific strategies in isolation. Further study on the impact of individual professional development practices would provide feedback for which strategies offer the strongest benefits.

**Impact on Classroom Instruction.** This study provides a foundation for working with teachers, but further study centered on other factors that impact implementation,

including coaching models, the role of the principal, the expertise of the curriculum director, and the level of support from the superintendent and school board. That support would strengthen the literature base for making systemic change. After all, for complete implementation of the CCSSM to occur, the focus cannot be merely on teachers, as teachers change positions and move away. The focus cannot be only on schools, because school leadership and expectations shift. The focus must be on embedding the CCSSM into the culture of the district for sustainable change to occur and remain over time.

### **Relationship Between Measures of Teacher Knowledge and Student**

**Learning.** Upon reflection of the data collected for this study, a temporal element emerged that should be considered in future research. This issue spans three separate yet related issues: 1) alignment between the measures of teacher knowledge and student performance, 2) consideration of the curriculum scope and sequence in relation to the time of year in which the measures are administered, and 3) provision of practice time.

First, a comparative analyses of the contents included in the measures for teacher knowledge and student performance would facilitate greater sensitivity to the treatment at hand. For example, with the 2004 LMT, a focus is placed on number and operations. However, when using the Galileo student assessments, all mathematical domains are included. Therefore, the lack of alignment between the LMT and the Galileo makes it difficult to draw conclusions regarding the connections between teacher knowledge and student learning. Accounting for this relationship by better aligning the content would provide more robust data.

Second, the time of year in which the professional development is delivered has bearing on the opportunity for teachers to implement classroom strategies based on

specific content standards. For example, if teachers acquire place-value strategies during a course offered during the spring semester, but place value is taught during the fall semester, the opportunity to apply such strategies will not present itself during the time in which the course takes place. Therefore, alignment between the course goals, mathematics scope and sequence, and assessment administration is warranted.

A third temporal consideration that would benefit future study in this space comprises longer durations of time between the pre- and post-assessments in all three areas – teacher knowledge, classroom practice, and student learning. As teachers gain new knowledge and skills, they need time to integrate these into their repertoire – they need time to *practice*. Expecting teachers' new knowledge to show up in student performance prior to allowing sufficient time for them to refine their skill is both naïve and incongruous with the literature (Darling-Hammond, 2009; Desimone, 2009; Desimone, et al., 2002).

## **Limitations**

**Instrumentation.** Although the two forms of the LMT scale had been equalized by the designers, an administrative error occurred for which account must be made. The online version of the LMT randomly assigns one form of the test to participants for the pretest and then administers the opposite form for the posttest. However, when administering the posttest at the conclusion of the first treatment, I provided the incorrect code to the first experimental group. This resulted in only half of this group receiving the alternate form, whereas the other half received the same form taken in the pretest. A statistical analysis of the two LMT forms suggested that the forms were not equivalent, which may have skewed the results and analytics.

**Selection bias.** To address issues of selection bias in the matching process (Question 2), every attempt was made to select matched pairs of teachers who resembled one another on the presage variables (Shadish et al., 2002) regarding student demographics. Selections were made after the pretest was administered based on similar-scoring experimental-comparison matched pairs who taught at the same school. However, as previously divulged, a poststudy examination of LMT Forms A and B appeared to indicate that the forms are not equivalent, contrary to the authors' claims. Statistically significant differences were found between the treatment and control teachers who participated in the case studies, but selection bias may have occurred, despite attempts to minimize it.

**Selection-maturation interaction.** Treatment 2 occurred later in the school year, thus providing opportunities for the experimental teachers to acquire knowledge prior to the beginning of their treatment. That said, growth scores on the LMT and on the sorting task indicate that similar gains were made over the course of the year for both groups, once they had engaged in the CCSSM course.

**Interaction effects.** Although participants in the experimental group were asked to not divulge their experiences with colleagues in the comparison group, the possibility exists that contamination took place because the random-assignment process facilitated teachers at the same school to be assigned to different groups.

**Small sample size.** Only 37 teachers participated in this study. This sample is small for determining an effect using the LMT, which claims sensitivity to determine an effect with a sample of 60 or more participants. In addition, the student-assessment data

did not reveal a statistically significant difference, which may be due to a lack of power resulting from a small sample size.

**Multiple interference.** Other professional development opportunities existed during the course of this treatment. However, participant reports, district administrator responses, and examination of other presentation materials indicated that there was very little overlap with the treatment offered in this professional development opportunity. In fact, whenever possible, integration of other training materials was included (e.g., district pacing guides; word problem types). Furthermore, the district attempted to limit the amount of nonmathematics professional learning given to these teachers during the treatment year.

**Experimental mortality.** In each group, one teacher left the district prior to beginning the treatment, and one teacher did not attend the final class or take the posttest due to childbirth. For the teacher who went on maternity leave, the LMT and sorting-task scores were removed because no posttest score was collected, but the student scores were still used because the teacher attended all course activities up until the final day.

**Observation-interview design elements.** This work would be enhanced by increasing the level of rigor of the observations and interviews by (a) including a video element to which teachers can respond and for which researchers can code, and (b) reframing the interview questions to focus on specific professional development components rather than only on teacher decision making.

**Reliability in qualitative analysis.** Because a single researcher analyzed the qualitative data sets, no inter-coder reliability was established. This study would benefit from the use of multiple analysts to codesign, review, and refine the inclusion rules and



coding schemes used for analyzing the semistructured stimulated-recall interviews, participant reflections, and field notes referenced throughout this dissertation.

### **Summary**

During the analysis phase, this study revealed that the professional development treatment made its greatest impact on teacher knowledge and its smallest impact on student learning. These results may be attributed to a variety of causes. First, the CCSSM course itself was only 3 months in duration for each single group, which may not be enough time to detect the desired changes in student learning. Second, the sample size was quite small for the analytic methods selected for this study. Third, returning to the modified professional development framework introduced in Chapter 2 (Figure 6), there may be diminishing returns in the results based on the number of mediating variables between the professional development treatment and each of the selected outputs: teacher knowledge, classroom practice, and student learning. Further study is warranted to examine the relationship between the treatment's relationship with classroom implementation and student learning beyond the teachers' conceptions and the analysis of student performance on benchmark assessments.

As stated in the introduction, success of the CCSSM is yet to be determined, and will depend greatly on classroom implementation by a teaching force that is currently unprepared for the task (Cobb & Jackson, 2011; Porter et al., 2011; Schmidt & Houang, 2012). As Cobb and Jackson (2011) stated, "It is one thing to formulate sound instructional policies and another to support their successful implementation." Changing the way students interact with and apply mathematics requires that teachers shift their classroom practices in significant and profound ways.

This efficacy study set out to determine the effect of one CCSSM-based professional development model on teacher knowledge, classroom implementation, and student learning. Evidence revealed that this course successfully impacted teacher knowledge, slightly impacted classroom practice on a small scale, but did not significantly impact student learning. Because teachers largely lack the knowledge and support needed to fully implement standards-based teaching and learning (Confrey, 2007; Jardine et al., 2008; Kaufman & Stein, 2010; Lappan, 1997), and because teachers are the primary decision makers in the planning and execution of classroom-level instruction, the success of standards-based teaching depends greatly on systemic professional learning opportunities for teachers. The treatment designed for this study provides one perspective for the beginning of the journey, successfully changing teacher knowledge, but further work is yet to be done to find ways to impact classroom implementation on a large scale, and, ultimately, student learning in meaningful ways.

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APPENDIX A

GUIDING DOCUMENTS FOR QUALITATIVE ANALYSES

## Mathematical Knowledge for Teaching (MKT) Descriptors

<b>Subject Area Knowledge</b>	
<b>1) Common Content Knowledge (CCK)</b>	<b>2) Specialized Content Knowledge (SCK)</b>
<p>We call this <i>common content knowledge (CCK)</i> and define it as the mathematical knowledge and skill used in settings other than teaching ... By “common,” however, we do not mean to suggest that everyone has this knowledge. Rather, we mean to indicate that this is knowledge of a kind used in a wide variety of settings—in other words, not unique to teaching.</p> <p>Recognize when students give wrong answers.            Recognize when the textbook gives an inaccurate definition.            Use terms and notation correctly.            Be able to do the work assigned to students.            Pronounce terms correctly.            Calculate correctly.            Understand the mathematics in the student curriculum.            Examples: What number lies between 1.1 and 1.11?            Is a square a rectangle? Does <math>0/7 = 0</math>? Are diagonals of a parallelogram perpendicular?</p>	<p>The second domain, <i>specialized content knowledge (SCK)</i>, is the mathematical knowledge and skill unique to teaching ... Close examination reveals that SCK is mathematical knowledge not typically needed for purposes other than teaching.</p> <p>Looking for patterns in student errors.            Sizing up whether a nonstandard approach would work in general.            “An uncanny kind of unpacking of mathematics that is not needed—or even desirable—in settings other than teaching.”            Knowledge beyond that being taught to students.            Understanding different interpretations of the operations <i>in ways that students need not explicitly distinguish</i>.            Figuring out which types of problems fit with which operations.            Use of “decompressed mathematical knowledge” that might be taught directly to students as they develop understanding ... Teachers must hold unpacked mathematical knowledge ... to make features of particular content visible to and learnable by students.            Talk explicitly about how mathematical language is used.            How to choose, make, and use mathematical representations effectively.            How to explain and justify one’s mathematical ideas.            Examples:</p> <ul style="list-style-type: none"> <li>o Appreciating the differences between “take-away” and “comparison” models of subtraction.</li> <li>o Distinguishing between “measurement” and “partitive” models of division.</li> <li>o Teaching about place value</li> </ul>
<b>Horizon Content Knowledge (HCK)</b>	
<p>We also provisionally include a third category within subject matter knowledge, what we call “horizon knowledge” (Ball, 1993). Horizon knowledge is an awareness of how mathematical topics are related over the span of mathematics included in the curriculum.</p> <p>Includes the vision useful in seeing connections to much later mathematical ideas.            Can help in making decisions about how, for example, to talk about the number line.            Might it matter how a teacher’s choices anticipate or distort later development</p>	

<b>Pedagogical Content Knowledge</b>	
<b>3) Knowledge of Content and Students (KCS)</b>	<b>4) Knowledge of Content and Teaching (KCT)</b>
<p>The third domain, <i>knowledge of content and students (KCS)</i>, is knowledge that combines knowing about students and knowing about mathematics.</p> <p>Anticipate what students are likely to think and what they will find confusing.</p> <p>Predict which examples students will find interesting and motivating.</p> <p>Anticipate what students are likely to do with a task and whether they will find it easy or hard.</p> <p>Hear and interpret students' emerging and incomplete thinking as expressed in the ways that pupils use language.</p> <p>Knowledge of common students conceptions and misconceptions about particular mathematical content.</p> <p>Familiarity with common errors and deciding which of several errors students are most likely to make.</p> <p>Draws from literature by van Heile, CGI, fractions.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>o Shapes young students are likely to ID as triangles,</li> <li>o Knowing why students may write 405 for 45,</li> <li>o Awareness of the common confusion between area and perimeter</li> </ul>	<p>The last domain, <i>knowledge of content and teaching (KCT)</i>, combines knowing about teaching and knowing about mathematics. Many of the mathematical tasks of teaching require a mathematical knowledge of the design of instruction.</p> <p>Sequence instruction.</p> <p>Choose &amp; sequence examples.</p> <p>Evaluate the instructional advantages and disadvantages of representations.</p> <p>Deciding which student contributions to pursue, which to ignore, and which to save till later.</p> <p>Decide when to ask for more clarification.</p> <p>When to use a student's remark to make a mathematical point.</p> <p>When to pause, ask a new question, or pose a new task.</p> <p>Example:</p> <ul style="list-style-type: none"> <li>o Knowing instructionally viable models for place value, what each can reveal about the subtraction algorithm, and how to deploy them effectively (money vs. bundles vs. base-10 blocks vs. unifix cubes—and knowing when to use which for any particular student)</li> </ul>
<b>Knowledge of Content and Curriculum (KCC)</b>	
<p>We have provisionally placed Shulman's third category, curricular knowledge, within pedagogical content knowledge. We are not yet sure whether this may be a part of our category of knowledge of content and teaching or whether it may run across the several categories or be a category in its own right.</p>	

**1. Make sense of problems and persevere in solving them.**

Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. They consider analogous problems, and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Older students might, depending on the context of the problem, transform algebraic expressions or change the viewing window on their graphing calculator to get the information they need. Mathematically proficient students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends. Younger students might rely on using concrete objects or pictures to help conceptualize and solve a problem. Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, “Does this make sense?” They can understand the approaches of others to solving complex problems and identify correspondences between different approaches.

**2. Reason abstractly and quantitatively.**

Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to *decontextualize*—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to *contextualize*, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.

**3. Construct viable arguments and critique the reasoning of others.**

Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct

logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.

#### **4. Model with mathematics.**

Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

#### **5. Use appropriate tools strategically.**

Mathematically proficient students consider the available tools when solving a mathematical problem. These tools might include pencil and paper, concrete models, a ruler, a protractor, a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software. Proficient students are sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. For example, mathematically proficient high school students analyze graphs of functions and solutions generated using a graphing calculator. They detect possible errors by strategically using estimation and other mathematical knowledge. When making mathematical models, they know that technology can enable them to visualize the results of varying assumptions, explore consequences, and compare predictions with data. Mathematically proficient students at various grade levels are able to identify relevant external mathematical resources, such as digital content located on a website, and use them to pose or solve problems. They are able to use technological tools to explore and deepen their understanding of concepts.

**6. Attend to precision.**

Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give carefully formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

**7. Look for and make use of structure.**

Mathematically proficient students look closely to discern a pattern or structure.

Young students, for example, might notice that three and seven more is the same amount as seven and three more, or they may sort a collection of shapes according to how many sides the shapes have. Later, students will see  $7 \times 8$  equals the well remembered  $7 \times 5 + 7 \times 3$ , in preparation for learning about the distributive property. In the expression  $x^2 + 9x + 14$ , older students can see the 14 as  $2 \times 7$  and the 9 as  $2 + 7$ . They recognize the significance of an existing line in a geometric figure and can use the strategy of drawing an auxiliary line for solving problems. They also can step back for an overview and shift perspective. They can see complicated things, such as some algebraic expressions, as single objects or as being composed of several objects. For example, they can see  $5 - 3(x - y)^2$  as 5 minus a positive number times a square and use that to realize that its value cannot be more than 5 for any real numbers  $x$  and  $y$ .

**8. Look for and express regularity in repeated reasoning.**

Mathematically proficient students notice if calculations are repeated, and look both for general methods and for shortcuts. Upper elementary students might notice when dividing 25 by 11 that they are repeating the same calculations over and over again, and conclude they have a repeating decimal. By paying attention to the calculation of slope as they repeatedly check whether points are on the line through (1, 2) with slope 3, middle school students might abstract the equation  $(y - 2)/(x - 1) = 3$ . Noticing the regularity in the way terms cancel when expanding  $(x - 1)(x + 1)$ ,  $(x - 1)(x^2 + x + 1)$ , and  $(x - 1)(x^3 + x^2 + x + 1)$  might lead them to the general formula for the sum of a geometric series. As they work to solve a problem, mathematically proficient students maintain oversight of the process, while attending to the details. They continually evaluate the reasonableness of their intermediate results.



## Inclusion Rules—Participant Reflections

<b>Category</b>	<b>Code</b>	<b>Name</b>	<b>Definition</b>
A Activities	A-I	Workshop Interactions	Participant mentioned specific activities or experiences s/he engaged in as a result of this class that furthered his/her understanding or knowledge in the course. This may have been an experience that took place during the workshop or while completing the homework assignments. Examples: conversations, readings, simulations, video reflections
	A-CR	Classroom Activities	Participant mentioned specific activities presented during the workshop that could be directly used as resources or learning activities with students. Examples: games, activity sheets, lesson plans
D Dispositions	D-C	Confidence	Participant specifically mentioned an increase in confidence in his/her knowledge of mathematics content or teaching. Examples: confident, self-assured, more prepared
	D-E	Eagerness	Participant specifically mentioned an eagerness to use the strategies taught in the course. Examples: can't wait, asap, quickly, right away
	D-En	Enthusiasm	Participant expressed delight in the content of the course. Examples: benefit, excited, finally understand
	D-O	Overwhelmed	Participant specifically mentioned an apprehension regarding the new material. Example: overwhelmed
	D-St	Students	Participant specifically mentioned a shift in student dispositions regarding the math lessons taught from this course. Examples: students are excited, students have fun
MKT Mathematical Knowledge for Teaching	MKT-Gen	General	Participant made a general statement regarding Mathematical Knowledge for Teaching that did not fall into any specific subcategory.
PR Presenter-Researcher Reflections	PR-A	Affect	Presenter-researcher reflected on emotions regarding her emergence as a new researcher. Examples: frustration, exuberance, and uncertainty
	PR-PD	Professional Development	Presenter-researcher reflected on ways to improve the professional development design, either for this course or in the future. Examples: alterations to activities, deletions, additions
	PR-RD	Research Design	Presenter-researcher reflected on ways of improving the research design for this or future studies. Examples: limitations, errors, research questions
OS Organizational Structure	OS-SE	Supervision & Evaluation	Participant discussed frustrations and requested intervention with administrators regarding issues of supervision and evaluation. Examples: pacing guides, evaluation protocols, IEP procedures
	OS-R	Resources	Participant requested resources to assist him/her with implementing the CCSSM content standards and mathematical practices.

## Field Note Cluster Codes

Categories	Subcategories	Codes	Rules for inclusion
Dispositions	D-Eagerness	D-Eag	Participant specifically mentioned or demonstrated an eagerness to use the strategies taught in the course. Examples: can't wait, ASAP, quickly, right away
	D-Enthusiasm	D-Enth	Participant expressed or demonstrated delight in the content of the course. Examples: benefit, excited, finally understand, engaged, playful, positive
	D-Overwhelmed	D-O	Participant specifically mentioned an apprehension regarding the new material. Example: overwhelmed
	D-Students	D-St	Participant specifically mentioned a shift in student dispositions regarding the math lessons taught from this course. Examples: students are excited, students have fun
	D-Desire to understand	D-Und	Participants express a desire to understand the CC better; Participants state that they now have a better understanding
	D-Rapport-Cons	D-RappC	Participants expressed rapport with consultant and/or requested that the consultant act as liaison with administration; May also include advice-seeking beyond the content of the course
	D-Rapport-P	D-RappP	Participants demonstrating increased rapport with one another. Examples: share strategies and ideas with one another, stay after to chat
	D-Change	D-Ch	Participant referenced the change process. Examples: change is difficult, need time to practice
Evidence of learning	EL-Lack of understanding	EL-LU	Participants appear to lack understanding of the content at hand. That is, lack of responsiveness, incorrect answers, incomplete thoughts on the topic at hand, "loose translations," "sketchy responses"
	EL-Improved	EL-Imp	Participants demonstrate an improved understanding of the topic at hand
	EL-Clarification requested	EL-Clar	Participants request clarification
Extraneous comments		Ext	Comments that were nonessential facts. Examples: date, time, unrelated presenter comments
Logistics	Log-Research Design	Log-RD	Comments regarding the research design, measures, methods, etc.
	Log-PD	Log-PD	Comments regarding workshop design, schedule, organization
	Log-Group	Log-Gp	Information such as demographics
MKT	General	MKT-Gen	Participant made a general statement regarding Mathematical Knowledge for Teaching that did not fall into any specific subcategory.
General content knowledge	GCK-Understand mathematics in curriculum	GCK-UMC	Participants demonstrate an understanding of or inquire about the mathematics in the student curriculum
	GCK-Terms and Notation	GCK-TN	Participants demonstrate an understanding of or inquire about using terms and notation correctly

Categories	Subcategories	Codes	Rules for inclusion
Horizon content knowledge		HCK	Participants demonstrate an understanding of or inquire regarding how a teacher's choices anticipate or distort later development
Specialized content knowledge	SCK-Representation	SCK-Rep	Participants demonstrate an understanding of or inquire about how to choose, make, and use mathematical representations effectively
	SCK-Nonstandard approach	SCK-NSA	Participants demonstrate or inquire about a topic that requires an ability to size up whether a nonstandard approach will work
	SCK-Explain and justify	SCK-EJ	Participants demonstrate an understanding of or inquire about how to explain and justify mathematical thinking, both for self and for students
*Knowledge of content & curriculum	Structure	KCC-Struc	Structures the participants discover within and between the standards—may include comparisons across grade levels or the basic structure of the document itself
	Connections	KCC-Con	Connections participants identify within and between the standards as written or between different sets of standards (2008 AZ Math Standard, NCTM standards, etc.)
	KCC-Identify describe	KCC-ID	Participants identify standards that align with activities and/or describe the contents of the standards
**Knowledge of content & teaching	Connections	KCT-Con	Participants make connections between the standards and instruction, including integrating math topics or integrating math with other school subject
	Management	KCT-Mgt	Comments and/or requests regarding classroom and/or instructional management strategies related to standards implementation
	KCT-Evaluate	KCT-Eval	Participants evaluate, discuss, or are exposed to instructional advantages and disadvantages of representations and/or activities.
	KCT-Sequence	KCT-DS	Participants discuss, or are exposed to the design and/or sequencing of instruction
	KCT-Student contributions	KCT-SC	The participants demonstrate an understanding of or inquire about deciding which student contributions to pursue, which to ignore, and which to save till later
Knowledge of content & students	Capabilities	KCS-Cap	Comments regarding students' capabilities and capacities related to the common core standards
	Resources	KCS-Res	Participants commented about or requested materials or resources focused on students
	KCS-Anticipate	KCS-Ant	Participants demonstrate an understanding of or inquire about anticipating what students are likely to think and what they will find confusing
	KCS-Interpret	KCS-Int	Participants examine and interpret student work with an emphasis on making generalizations and recommendations for future work
	KCS-Conceptions and misconceptions	KCS-CM	Participants demonstrate an understanding of or inquire about matters regarding the knowledge of common student conceptions and misconceptions about particular mathematical content

Categories	Subcategories	Codes	Rules for inclusion
District Constraints	DC-Concern	DC-Conc	Participants express concern with district structures such as professional development, assessment, etc.
	DC-CCSSM resources	DC-Res	Participants comment on the deficient or lack of common core resources offered by district and/or request resources to assist them with implementing the CCSSM
	DC-Suggestion & acknowledgement	DC-SA	Consultant made a recommendation to the district personnel, and they acknowledged the issue
	DC-Supervision & evaluation	DC-SE	Participant discussed frustrations and requested intervention with administrators regarding issues of supervision and evaluation. Examples: pacing guides, evaluation protocols, IEP procedures
	DC-Connection	DC-Con	Participants reference connections between the class and structures that already exist in their district
Presenter-researcher reflections	PR-Affect	PR-A	Presenter-researcher reflected on emotions regarding her emergence as a new researcher. Examples: frustration, exuberance, and uncertainty
	Professional development	PR-PD	Presenter-researcher reflected on ways to improve the professional development design, either for this course or in the future. Comments may also reflect effectiveness of activities at hand. Examples: alterations to activities, deletions, additions, effective
	Research design	PR-RD	Presenter-researcher reflected on ways of improving the research design for this or future studies. Examples: limitations, errors, research questions
Standards for mathematical practice	MP-Problem solving	MP1	Participants referenced, discussed, or engaged in activities specifically involving the problem solving practices outlined in the CCSSM (make sense of problems and persevere in solving them).
	MP-Reasoning	MP2	Participants referenced, discussed, or engaged in activities specifically involving the reasoning practices outlined in the CCSSM (reasons abstractly and quantitatively).
	MP-Explaining	MP3	Participants referenced, discussed, or engaged in activities specifically involving the “explaining” practices outlined in the CCSSM (creates viable arguments and critiques the arguments of others).
	MP-Modeling with mathematics	MP4	Participants referenced, discussed, or engaged in activities specifically involving the mathematical modeling practices outlined in the CCSSM models with mathematics).
	MP-Using tools	MP5	Participants referenced, discussed, or engaged in activities specifically involving the “tools” practices outlined in the CCSSM uses appropriate tools strategically).
	MP-Using precision	MP6	Participants referenced, discussed, or engaged in activities specifically involving the precision practices outlined in the CCSSM (uses precision).
	MP-Structure	MP7	Participants referenced, discussed, or engaged in activities specifically involving the “structure” practices outlined in the CCSSM look for and make use of structure).

Categories	Subcategories	Codes	Rules for inclusion
	MP-Using Repeated Reasoning	MP8	Participants referenced, discussed, or engaged in activities specifically involving the “repeated reasoning” practices outlined in the CCSSM (look for and find regularity in repeated reasoning).
Workshop activities	WSA-Standards	WSA-Stand	Participants engaged in activities or experiences intended to further their understanding or knowledge of the CCSSM. These may have been an experience that took place during the workshop or while completing the homework assignments. Examples: conversations, readings, simulations, video reflections
	WSA-Classroom	WSA-CR	Participants engaged in specific activities presented during the workshop that could be directly used as classroom resources or learning activities with students. Examples: games, activity sheets, lesson plans (NOTE: all WSA-CR activities are a subset of WSA-Stand as they are intended to illustrate the CCSSM through activities that can be used with children)

APPENDIX B  
IRB APPROVAL

**To:** James Middleton  
Payne

**From:** Mark Roosa, Chair  
Soc Beh IRB

**Date:** 06/06/2011

**Committee Action:** Exemption Granted

**IRB Action Date:** 06/06/2011

**IRB Protocol #:** 1105006515

**Study Title:** Teachers as Learners: Professional Development for  
Standards-Based Mathematics Teaching and Learning

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1).

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.

APPENDIX C  
TREATMENT—OUTLINE OF ACTIVITIES



Session	Activities
1	<ul style="list-style-type: none"> <li>· Pretests: LMT and Online Sorting Task</li> <li>· Introductions and goals</li> <li>· Content Standards Introduction</li> <li>· Student Task: place value task</li> <li>· Standards Talk: Numbers Base Ten (NBT—place value)</li> <li>· Workshop: Numbers Base Ten (NBT—place value)</li> <li>· Work Session</li> <li>· Personal Reflections and Feedback</li> </ul>
2	<ul style="list-style-type: none"> <li>· Warm-up Task: place value task</li> <li>· Book Talk: chapters on student-centered math and place value (read beforehand)</li> <li>· Student Work Analysis: place value task</li> <li>· Standards for Mathematical Practice (SMP) Introduction</li> <li>· Standards Talk: Numbers Base Ten (NBT—operations)</li> <li>· Workshop: Numbers Base Ten (NBT—operations)</li> <li>· Work Session</li> <li>· Personal Reflections and Feedback</li> </ul>
3	<ul style="list-style-type: none"> <li>· Warm-up task: number line task</li> <li>· Book Talk: chapters on math facts and operations</li> <li>· Student Work Analysis: place value task</li> <li>· Workshop: Mental math</li> <li>· SMP Review—created “kid-friendly” posters</li> <li>· Standards Talk: Numbers Base Ten (NBT—operations)</li> <li>· Workshop: Number Lines</li> <li>· Standards Talk: Operations and Algebraic Thinking (OA—math facts)</li> <li>· Workshop: Math Facts</li> <li>· Work Session</li> <li>· Personal reflections and feedback</li> </ul>
4	<ul style="list-style-type: none"> <li>· Warm-up Task: problem types task</li> <li>· Book Talk: chapters on word problems, clock reading, and algebraic thinking</li> <li>· Student Work Analysis: number line task</li> <li>· SMP Review</li> <li>· Mid-course Reflection—completed individual written reflections</li> <li>· Standards Talk: OA (word problems)</li> <li>· Workshop: OA (word problems, including CGI problem types)</li> <li>· Standards Talk: Measurement and Data (MD—time and money)</li> <li>· Workshop: Time and money</li> <li>· Work Session</li> <li>· Personal Reflections and Feedback</li> </ul>
5	<ul style="list-style-type: none"> <li>· Warm-up Task: data analysis task</li> <li>· Book Talk: chapters on measurement, data, and multiplication</li> <li>· Student Work Analysis: problem types task</li> </ul>

Session	Activities
	<ul style="list-style-type: none"> <li>· SMP Review</li> <li>· Standards talk: OA (multiplication)</li> <li>· Workshop: OA (multiplication)</li> <li>· Standards Talk: MD (measurement and data)</li> <li>· Workshop: Measurement and Data</li> <li>· Work Session</li> <li>· Personal Reflections and Feedback</li> </ul>
6	<ul style="list-style-type: none"> <li>· Book Talk: chapters on geometry and fractions</li> <li>· Student Work Analysis: data analysis task</li> <li>· SMP Review</li> <li>· Standards Talk: Fractions</li> <li>· Workshop: Fractions</li> <li>· Posttests: LMT and Online Sorting Task</li> <li>· Standards Talk: Geometry</li> <li>· Workshop: Geometry</li> <li>· Community Circle (public sharing of what they learned)</li> <li>· End-of-course Reflections and Feedback</li> </ul>

APPENDIX D  
INSTRUMENTATION

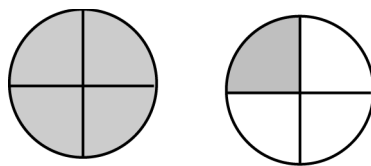
Learning Mathematics for Teaching (LMT)—Sample Released Items

1. Ms. Dominguez was working with a new textbook and she noticed that it gave more attention to the number 0 than her old book. She came across a page that asked students to determine if a few statements about 0 were true or false. Intrigued, she showed them to her sister who is also a teacher, and asked her what she thought.

Which statement(s) should the sisters select as being true? (Mark YES, NO, or I'M NOT SURE for each item below.)

	Yes	No	I'm not sure
a) 0 is an even number.	1	2	3
b) 0 is not really a number. It is a placeholder in writing big numbers.	1	2	3
c) The number 8 can be written as 008.	1	2	3

5. Mrs. Johnson thinks it is important to vary the whole when she teaches fractions. For example, she might use five dollars to be the whole, or ten students, or a single rectangle. On one particular day, she uses as the whole a picture of two pizzas. What fraction of the two pizzas is she illustrating below? (Mark ONE answer.)



- a)  $\frac{5}{4}$
- b)  $\frac{5}{3}$
- c)  $\frac{5}{8}$
- d)  $\frac{1}{4}$

12. Mrs. Jackson is getting ready for the state assessment, and is planning mini-lessons for students focused on particular difficulties that they are having with adding columns of numbers. To target her instruction more effectively, she wants to work with groups of students who are making the same kind of error, so she looks at a recent quiz to see what they tend to do. She sees the following three student mistakes:

I) $\begin{array}{r} 1 \\ 38 \\ 49 \\ + 65 \\ \hline 142 \end{array}$	II) $\begin{array}{r} 1 \\ 45 \\ 37 \\ + 29 \\ \hline 101 \end{array}$	III) $\begin{array}{r} 1 \\ 32 \\ 14 \\ + 19 \\ \hline 64 \end{array}$
---	--	--

Which have the same kind of error? (Mark ONE answer.)

- a) I and II
- b) I and III
- c) II and III
- I, II, and III

13. Ms. Walker’s class was working on finding patterns on the 100s chart. A student, LaShantee, noticed an interesting pattern. She said that if you draw a plus sign like the one shown below, the sum of the numbers in the vertical line of the plus sign equals the sum of the numbers in the horizontal line of the plus sign (i.e.,  $22 + 32 + 42 = 31 + 32 + 33$ ). Which of the following student explanations shows sufficient understanding of why this is true for all similar plus signs? (Mark YES, NO or I’M NOT SURE for each one.)

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

- |  | Yes | No | I’m not sure |
|--|-----|----|--------------|
| a) The average of the three vertical numbers equals the average of the three horizontal numbers.           | 1   | 2  | 3            |
| b) Both pieces of the plus sign add up to 96.  | 1   | 2  | 3            |
| c) No matter where the plus sign is, both pieces of the plus sign add up to three times the middle number. | 1   | 2  | 3            |
| d) The vertical numbers are 10 less and 10 more than the middle number.                                    | 1   | 2  | 3            |

14. Mrs. Jackson is getting ready for the state assessment, and is planning mini-lessons for students around particular difficulties that they are having with subtracting from large whole numbers. To target her instruction more effectively, she wants to work with groups of students who are making the same kind of error, so she looks at a recent quiz to see what they tend to do. She sees the following three student mistakes:

I	II	III
$\begin{array}{r} 4 \ 12 \\ \cancel{502} \\ - \ 6 \\ \hline 406 \end{array}$	$\begin{array}{r} 4 \ 15 \\ \cancel{35005} \\ - \ 6 \\ \hline 34009 \end{array}$	$\begin{array}{r} 6 \ 9 \ 8 \ 15 \\ \cancel{7005} \\ - \ 7 \\ \hline 6988 \end{array}$

Which have the same kind of error? (Mark ONE answer.)

- a) I and II
- b) I and III
- c) II and III
- d) I, II, and III

## Online Sorting Task

The screenshot below shows the directions provided to each participant at the beginning of the online sorting task.



The screenshot below shows the initial view of the online sorting task prior to beginning the drag-and-drop sort.

Galileo—Sample Items

4) Which is true?

A)  $68 < 20 + 20 + 8$

B)  $68 = 20 + 20 + 8$

C)  $68 > 20 + 20 + 8$

---

6) Which answer is less than 50?

A)  $34 + 44$

B)  $32 + 10$

C)  $51 + 16$

---

8) Which number is 100 more than 687?

A) 587

B) 637

C) 787

D) 837

---

10) Jose had 43 grapes. He ate 15 grapes. How many grapes does he have left now?

Which will give the right answer?

A)  $43 + 15 = 58$

B)  $43 + 15 = 48$

C)  $43 - 15 = 32$

D)  $43 - 15 = 28$

---

- 13) Count the money.

How much money is shown?



- A) 57¢
  - B) 77¢
  - C) 82¢
  - D) 85¢
- 

- 14) What number goes in the box to make this number sentence true?

$$40 + 8 = \square + 40$$

- A) 8
  - B) 32
  - C) 40
  - D) 48
- 

- 18) There are five houses. Each house has five windows. How many windows are there altogether?

 5  
windows 5

- A) 0
  - B) 10
  - C) 20
  - D) 25
-

20) What time is it?



- A) 1:00
  - B) 1:30
  - C) 2:00
  - D) 2:30
- 

27) The girls scored 43 points in the first half of the game and 48 points in the second half.

How many total points did they score?

- A) 78
  - B) 88
  - C) 81
  - D) 91
- 

31) Which answer is smaller than the number in the circle?

- A)  $\textcircled{7} + 1 =$
  - B)  $\textcircled{7} + 7 =$
  - C)  $\textcircled{7} - 0 =$
  - D)  $\textcircled{7} - 1 =$
- 

37) A number has two ones, eight tens, and seven hundreds. What is the number?

- A) 827
  - B) 782
  - C) 287
  - D) 218
-

38) Which number will make the number sentence true?

$$(4 + 9) + 3 = \square + (9 + 3)$$

- A) 3
  - B) 4
  - C) 9
  - D) 12
- 

44) Which is a way to add  $7 + 8$ ?

- A) Add  $8 + 8$  and add 1.
  - B) Add  $7 + 7$  and add 1.
  - C) Add  $7 + 8$  and add 1.
  - D) Add  $7 + 7$  and subtract 1.
-

Observation Protocol

**Reformed Teaching Observation Protocol (RTOP)**

*Daiyo Sawada*      *Michael Piburn*  
External Evaluator      Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom  
*Evaluation Facilitation Group (EFG)*

Technical Report No. IN00-1  
Arizona Collaborative for Excellence in the Preparation of Teachers  
Arizona State University

**I. BACKGROUND INFORMATION**

Name of teacher \_\_\_\_\_ Announced Observation? \_\_\_\_\_  
(yes, no, or explain)

Location of class \_\_\_\_\_  
(district, school, room)

Years of Teaching \_\_\_\_\_ Teaching Certification \_\_\_\_\_  
(K-8 or 7-12)

Subject observed \_\_\_\_\_ Grade level \_\_\_\_\_

Observer \_\_\_\_\_ Date of observation \_\_\_\_\_

Start time \_\_\_\_\_ End time \_\_\_\_\_

**II. CONTEXTUAL BACKGROUND AND ACTIVITIES**

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Record here events which may help in documenting the ratings.

Time	Description of Events

### III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive					
		0	1	2	3	4	0	1	2	3	4
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4					
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4					
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4					
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4					
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4					

### IV. CONTENT

#### Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4					
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4					
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4					
9)	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4					
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4					

#### Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4					
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4					
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4					
14)	Students were reflective about their learning.	0	1	2	3	4					
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4					



**V. CLASSROOM CULTURE**

	<b>Communicative Interactions</b>	<b>Never Occurred</b>				<b>Very Descriptive</b>			
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4			
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4			
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4			
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4			
20)	There was a climate of respect for what others had to say.	0	1	2	3	4			
	<b>Student/Teacher Relationships</b>								
21)	Active participation of students was encouraged and valued.	0	1	2	3	4			
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4			
23)	In general the teacher was patient with students.	0	1	2	3	4			
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4			
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4			

Additional comments you may wish to make about this lesson.

## Interview Protocol

### BEFORE OBSERVATION:

“After the observation, I’ll be asking you to describe a point in the lesson where you made a significant decision regarding the math you were teaching.”

### DURING OBSERVATION:

Identify a point in the lesson where the teacher makes a significant decision regarding the math s/he is teaching, in the event that s/he does not identify such a point on his/her own.

### AFTER OBSERVATION:

1. “Describe a point in the lesson where you made a significant decision regarding the math you were teaching.” (NOTE: Be prepared to identify such a point for the teacher if s/he can’t do so him/herself.)
  
2. “Describe what were you thinking as you made that decision?”
  - a. If needed, say, “What did you see the student(s) do that prompted your decision?”
  
3. “Here’s an example of the different kinds of knowledge teachers use when they’re making decisions while teaching math. [Show chart—describe briefly as needed.] Which of these do you think had an impact on your decision? Describe how your knowledge in these areas had an impact?”

Interview Protocol (cont.)

**Mathematical Knowledge for Teaching**

Adapted from Deborah Ball, et al., 2008

