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Decades of research on mathematics teaching have identified fundamental instructional practices that promote deep learning of mathematics for all students. In contrast with more traditional and direct approaches to teaching, these core instructional practices of mathematics instruction foster student engagement, understanding, and collaboration and represent a significant shift in the practice of teaching for many mathematics teachers. Though recent efforts by mathematics teacher educators have focused on assisting novices to learn core practices in teacher preparation programs, there is little research on the ways teachers learn to enact these practices in professional development.

The purpose of this study is to understand teachers' learning in mathematics professional development focused on the core practice of leading mathematics discussions and changes in their classroom enactments of the practice. This multiple case study investigates four teachers' trajectories of participation as they engaged in 108 hours of professional development designed to assist teachers in learning to lead mathematics discussions. Video recordings of professional development sessions and classroom enactments, interviews, and teacher journals were analyzed to understand how these four teachers' patterns of participation in the professional development related to their practice of leading discussions in their classrooms.

Though each of the four teachers' participation over time was unique, findings indicated that three teachers' trajectories of participation, which resulted in an alignment

between learning in the professional development and in classroom enactments, centralized student learning and led to full membership in the emerging professional development community. In contrast, a persistent focus on her own learning that characterized the fourth teacher's trajectory did not enable her to align her learning and practice, and yielded only marginal participation in the community. These results suggest that teachers with established professional identities and strong commitments to student learning were able to transform their identities as reform mathematics teachers, negotiate multi-membership, and span boundaries across perspectives. The study's implications for district leaders making decisions about mathematics professional development, teacher educators working with teachers to improve their practice of leading mathematics discussions, and researchers examining teacher learning and instructional change are discussed.

EXPLORING TEACHERS' LEARNING OF INSTRUCTIONAL PRACTICE IN PROFESSIONAL DEVELOPMENT

by

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Approved by

_____
Committee Chair

To the amazing teachers I am blessed to work with each day. These teachers strive daily to help their students understand and love mathematics. You are an inspiration to me!

To my parents, Phyllis and Larry Lupton

To my best friend and partner, Wendy Rich

APPROVAL PAGE

This dissertation, written by Ana Lupton Floyd, has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

The central tenet of the education reform efforts of the last three decades is that all students can learn and achieve at high levels. Though wrought with challenges, reform efforts have led to significant improvements in education (National Council of Teachers of Mathematics [NCTM], 2014). Whereas only 29% of fourth-grade students in the U.S. were considered proficient in reading on the NAEP in 1992, the latest results indicated 35% of fourth graders performed at or above proficient in 2013 (NAEP, 2013). In mathematics, the average mathematics score on the TIMSS assessment at grade 4 was 23 points higher in 2011 compared with scores in 1995 (TIMSS, 2012).

Reform efforts have been driven by changes to curriculum standards outlining the content students should learn (Common Core State Standards, 2010; NGSS Lead States, 2013) as well as the instructional approaches that best support students' learning (NCTM, 1989, 1991, 2000). In mathematics, the National Council of Teachers of Mathematics's (2000) *Principles and Standards for School Mathematics* and the Common Core State Standards for Mathematics (CCSSM, 2010) have advanced reform efforts by articulating not only the mathematics content to be learned, but also a clear vision for classroom environments that support students' mathematical learning. These learning environments provide opportunities for students to engage with meaningful tasks, communicate their

mathematical reasoning, connect between multiple strategies and representations, and develop both conceptual understanding and procedural fluency.

To support students in meeting these standards, new models of instruction that emphasize inquiry-based approaches and promote reasoning and flexible problem solving have emerged based on research on learning and teaching. In contrast with a traditional and direct model of instruction, these new instructional approaches foster student engagement, understanding, and collaboration. In a move that summarized research on mathematics teaching, NCTM's (2014) *Principles to Actions: Ensuring Mathematical Success for All* outlined a set of eight mathematics teaching practices that center instruction on students, such as implementing problem solving tasks, facilitating mathematical discourse, posing purposeful questions, and supporting students' productive struggle in learning mathematics. Grounded in research on mathematics teaching, these instructional practices are fundamental to promoting deep learning of mathematics for all students and represent a significant departure from many mathematics teachers' practice of teaching (Hiebert & Stigler, 2000; Hiebert, Stigler, & Jacobs, 2005; Weiss, Pasley, Smith, Banilower, & Heck, 2003).

Statement of Research Problem

In teacher education, these emerging, research-based instructional strategies are referred to as core practices (Forzani, 2014; Jacobs & Spangler, in press; McDonald, Kazemi, & Kavanagh, 2013). Core practices summarize the knowledge base on mathematics teaching and outline instructional strategies that promote student mathematical learning. Core practices identify the complex practices associated with

high-quality mathematics instruction and offer tools for implementing teaching practices that require in-the-moment decision-making. An example of a research-based core practice is leading mathematics discussions.

In contrast with established, long-held approaches to teaching, these core instructional practices of mathematics instruction foster student engagement, understanding, and collaboration and represent a significant shift in the practice of teaching. Not surprisingly, learning these core practices may be extremely challenging for some teachers to learn (Krupa, 2011). The teacher-centered paradigm is pervasive in many classrooms and controlled by cultural beliefs by both parents and educators that mathematics should be taught by memorization and practice (Handal, 2003; Philipp et al., 2007; Sam & Ernest, 2000). Yet reform efforts, specifically the CCSSM, "represent a significant departure from *what* mathematics is currently taught in most classrooms and *how* it is taught" (Sztajn, Marrongelle, & Smith, 2011, p. 3). Fostering and maintaining a learning environment that promotes student reasoning is challenging and places enormous demands on teachers (Sherin, 2002). Assisting teachers in learning these innovative and high-quality teaching practices is complex and demanding (Huinker, Leinwand, & Brahier, 2014; Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010), requiring dramatic reforms in our current mathematics programs.

With the implementation the CCSSM across the nation and a push for high-quality mathematics instruction, mathematics professional development is vital. For teachers to successfully meet the challenges of new standards, they should be provided opportunities to learn the new standards as well as core practices to promote student

learning (Cohen & Hill, 2001; Elmore, 2002). As claimed by Birman, Desimone, Porter, and Garet (2000), "if teachers are expected teach to new standards, including complex thinking skills, it is essential that they have a sophisticated understanding of the content and of how students learn the content" (p. 30). The promises of new mathematics standards will only be fulfilled through sustained and focused professional development opportunities (Sztajn et al., 2011).

Yet many professional development opportunities available to teachers are ineffective at improving teachers' knowledge and skills or changing teachers' instructional practice (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). Described by Elmore (2002) as ineffective, unfocused, and inconsistent, most professional development available for teachers involves short, one-time workshops in which information, instructional methods, or resources are disseminated to teachers. Occurring afterschool or at off-site training locations, facilitators of these professional development sessions may model skills, demonstrate strategies, deliver content, or share procedures related to the classroom. Based on dated theories of learning, these types of experiences assume learning is an individual process of acquisition and a discrete activity separate from everyday practice. From this perspective, knowledge about teaching and learning is decontextualized and presumably transmitted to others. Such professional development activities largely fail to significantly impact teacher practice (Darling-Hammond et al., 2009; Elmore, 2002).

Over the last 20 years, researchers in teacher education have worked to characterize professional development that provides meaningful learning opportunities

for teachers. Their work has led to a set of characteristics of professional development that promote teacher learning and student achievement, and recommendations for how professional learning can be transformed to potentially influence teacher practice (Ball & Cohen, 1999; Borko, 2004; Darling-Hammond & Richardson, 2009; Darling-Hammond et al., 2009; Desimone, 2009; Elmore, 2002; Guskey, 2003; Guskey & Yoon, 2009). Unfortunately, these features are rarely included and operationalized in the institutional school settings (Elmore, 2002), and providing high-quality professional development with these core features is challenging (Garet, Porter, Desimone, Birman, & Yoon, 2001). Mathematics teacher educators continue to wrestle with how to design effective professional development that supports teachers in not only learning core practices that align with the vision of high-quality mathematics but also practical ways to put these practices into action, resulting in a shift that promotes student mathematical thinking.

Statement of Purpose

The purpose of this study is to understand teachers' learning to enact the core practice of leading mathematics discussions in mathematics professional development. This multiple-case study investigated four mathematics teachers' participation as they engaged in 108 hours of professional development designed to assist teachers in learning to lead mathematics discussions. Using constructs from Wenger's (1998) communities of practice, it analyzed the four case teachers' learning, both in professional development and classroom settings, and charted changes in teachers' discourse related to learning the core practice. Specifically, this study sought to understand the various trajectories teachers took as they engaged in mathematics professional development with explicit

goals of learning to enact a core practice. This study addresses the broad research question: *In what ways does professional development affect teacher learning of the core practice of leading mathematics discussions?*

Significance of the Study

Well-established research on professional development underscores its importance and necessity in teachers' professional growth (Birman et al., 2000; Guskey, 2009). While the literature maintains the need for professional development, additional research is needed to understand the ways teachers learn to enact core practices as they participate in professional development. My research examined the different ways teachers learn in professional development in order to highlight factors that significantly affect teacher learning. The study has the potential to influence the way professional development is designed and ultimately enhance the impact on classroom practice and student learning.

Research Context

The Core Math II professional development project served as the context for this study. With the goal of preparing teachers to implement the core practice of leading discussions in the classroom in the elementary-grades, the Core Math II project involved two schools in a rural county in the Southeastern United States. Mathematics educators from a local university provided 108-hours of sustained professional development for 13 teachers at Hillside Elementary School and McDonald Elementary School, both considered schools with high needs. Funded by the state's ESEA Title II-A Improving Teacher Quality Grants program, the project provided teachers with 108 hours of in-

depth instruction on leading discussions and took place during the 2013–2014 school year.

Core Math II was designed based on characteristics of effective professional development described in the literature (Darling-Hammond et al., 2009; Desimone, 2009; Elmore, 2002). Results from an initial analysis conducted by the project's research team indicated that the Core Math II professional development was successful at supporting teachers in adopting the core practice of leading mathematics discussions (Wilson, Downs, & Duggan, 2014). Using a subset of the Instructional Quality Assessment (IQA) (Junker et al., 2004) to measure the academic rigor of instruction and classroom discourse of teachers' mathematics lessons, the research team assessed classroom instruction using pre and post video-recordings of mathematics lessons. Statistically significant ($0.00 \leq p \leq 0.09$) gains and moderate to strong effect sizes ($0.64 \leq d \leq 1.21$) in seven of the nine dimensions of the IQA reflected a shift from teacher-centered, traditional instruction to a focus on student mathematical thinking. Participants also completed the University of Michigan's Learning Mathematics for Teaching (LMT) (Hill & Ball, 2004) to measure gains in mathematics knowledge for teaching. The statistical significance ($p < 0.01$) and moderate effect size of the gains ($d = 0.595$) demonstrated that teachers' MKT improved as a result of participation in the professional development. These findings, along with project evaluation reports of self-reported changes in practice and growth in MKT (Downs & Hargrove, 2014), suggest that the project was an appropriate context to investigate teacher learning of the core practice of leading mathematics discussions

(LMD) in a professional development setting. Core Math II served as context for this study.

Core Math II was a part of a larger design experiment. Design experiments (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) are organized into three phases, including a design phase, an ongoing analysis phase, and a retrospective analysis (Cobb, 2000). Prior to entering candidacy, I completed the design, implementation, and ongoing analyses of one cycle of the design experiment in collaboration with the Core Math research team (Floyd, 2014; Rich, 2014). For this dissertation study, I employed case study methodology for a retrospective analysis of this first iteration to better understand teacher learning during the project. In this multiple case study, my goal was to analyze teacher learning and changes in practice by examining how four purposefully selected teachers learned in the professional development.

Outline of Dissertation

This dissertation is organized into five chapters. In Chapter I, I have introduced and outlined the significance of the research problem related to teachers learning to enact core practices in professional development. Chapter II reviews of the literature on teacher learning in professional development and outlines the theoretical framework for the study. In Chapter III, I justify my use of case study methods and describe the context, sample, data sources, and method of analysis used. In Chapter IV, I use Wenger's notion of participation to present the findings from the study that indicated a focus on student learning led to full membership in the professional development community for three of the participants, while the fourth participant's focus on her own learning yielded marginal

participation in the community. Chapter V contains a discussion including recommendations for future studies.

CHAPTER II

REVIEW OF THE LITERATURE AND THEORETICAL FRAMEWORK

This chapter provides a review of the research literature related to teacher learning in professional development settings that focus on participation and changes in instructional practices. I begin by reviewing the literature on teacher learning in professional development with attention to aspects of teachers' participation in professional communities. In the second section, I present a theoretical framework for my study, and then conclude with a set of refined research questions.

Teacher Learning in Professional Development

In an effort to provide meaningful learning opportunities for teachers, researchers in teacher education have worked to characterize essential elements of effective professional development. These characteristics offer recommendations for how professional learning can be transformed to promote teacher learning and potentially influence teacher practice and student achievement (Ball & Cohen, 1999; Borko, 2004; Darling-Hammond & Richardson, 2009; Darling-Hammond et al., 2009; Desimone, 2009; Elmore, 2002; Guskey, 2003; Guskey & Yoon, 2009). From research, effective professional development is characterized as intensive, ongoing, and sustained over time. It addresses specific content through active learning experiences and focuses on student learning. Additionally, it is coherent, aligned with school goals, and offers opportunities for collective participation and professional inquiry within learning communities.

In what follows, I outline two aspects related to teacher learning in mathematics professional development. The first section focuses on teacher learning through collective participation. The second section discusses teacher learning in professional development that is coherent and aligned.

Learning through Collective Participation

In learning communities, people learn by socially interacting with one another (Darling-Hammond & Bransford, 2005). Such contexts are supportive, respectful, and flexible. The community promotes a culture of collaboration, questioning, respect, and risk taking (Bransford, Brown, & Cocking, 2000; Cobb & McClain, 2006; National Research Council, 2005). Everyone values the various skills and interests of community members and supports the learning of all participants in the community.

Central to a learning community is the view that learning is collaborative and developed through the social interactions with others (Bransford et al., 2000). This holds true for both students and teachers. Research has consistently identified teacher collaboration as a necessity to improving instruction and student achievement (Darling-Hammond & Richardson, 2009; Loucks-Horsley & Matsumoto, 1999; Stein, Smith, & Silver, 1999). As a result, consensus documents report collaborative participation as an essential design element of quality professional development (Cohen & Hill, 2001; Desimone, 2009; Garet et al., 2001; Goldsmith, Doerr, & Lewis, 2013; Hill, Beisiegel, & Jacob, 2013). Opportunities for collaboration encourage teachers to examine their practice, develop and implement effective instructional methods, analyze student artifacts and data, provide feedback and support to one another, and discuss solutions to

challenging problems within the classroom (Darling-Hammond & Richardson, 2009; Loucks-Horsley & Matsumoto, 1999).

Whether analyzing student work samples, scrutinizing lesson plans and curriculum materials, or rehearsing a mathematical task with students, professional development must be designed to support teachers as they experiment with instructional practices (Kazemi & Hubbard, 2008). This is best accomplished with the help and encouragement of your professional colleagues. Therefore, effective professional development provides opportunities for teachers to collaboratively work together in learning communities or communities of practice (Ball & Cohen, 1999; Borko, 2004; Darling-Hammond et al., 2009; Elmore, 2002; Little, 1993; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Opher & Peddler, 2011; Sowder, 2007; Stein et al., 1999; Wenger, 1998). This collective endeavor enables teachers to jointly solve problems and discuss challenging learning situations. Strong relationships with colleagues and other experts provide teachers with the support they need to take risks, change the way they teach mathematics, and reflect on practice (Britt, Irwin, & Ritchie, 2001; Wood, Cobb, & Yackel, 1991).

In the extensive review and synthesis of 106 research studies related to mathematics teachers' learning, Goldsmith et al. (2013) found collaboration to be a key element to successful professional development that fosters teacher learning and instructional improvement. Study results indicated that teachers increase their content knowledge, modify their beliefs, and change their instructional practices by learning, collaborating, and supporting one another. The opportunities for collaboration helped

teachers build their understanding of mathematics as they attended to student thinking and discussed lessons or instruction (Grandau, 2005; Ticha & Hospesova, 2006).

Birman and colleagues (2000) found that collective participation promotes active learning experiences, encourages discussion about the concepts presented in training, contributes to a shared professional culture within the school, develops a common understanding of instructional goals, and allows for integration of other instructional content. Additionally, Franke, Carpenter, Levi, and Fennema (2001) found collaboration to be critical to teachers' ongoing learning and strongly contributes to their generative change and growth. The time together encourages teachers to share strategies, exchange ideas, reflect on their practice, and solve problems.

The following examples illustrate the ways professional development initiatives have capitalized on the learning potential of participation and interaction within learning communities (Battey & Franke, 2008; Cuddapah & Clayton, 2011; Franke et al., 2001; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Stein, Silver, & Smith, 1998). Battey and Franke (2008) document their experiences with fourth and fifth grade teachers who developed a community of mathematical learners where the teachers engaged in mathematical problems on a regular basis. Utilizing qualitative research methods such as videotapes, classroom observations, and interviews, the researchers analyzed the teachers' identities as mathematics teachers and highlighted the ways this identity influences their participation in the workgroups as well as implications in the classroom. They found that professional development that provides opportunities for teachers to work together encourages teachers to make sense of their knowledge, skills, and

identities. It helps them incorporate new practices and become "particular kinds of mathematics teachers" (Battey & Franke, 2008, p. 147).

When analyzing data from the workgroup meetings of ten teachers at one elementary school, Kazemi and Franke (2004) found that teachers' participation shifted as a result of their involvement in collaborative professional development. Shifts in participation provide evidence of teacher learning and changes in identity. The teachers discourse indicated that they were attending to the details of student thinking, recognizing and respecting students' mathematical competencies, and developing potential instructional trajectories. The discussions provided evidence of the teachers' transformation in the community of learners.

While learning communities offer teachers support as they learn, they should also challenge teachers to investigate, analyze, question, and even criticize instructional methods (Ball & Cohen, 1999; Goldsmith et al., 2013). Teachers should engage in provocative discourse about teaching and learning. They should critically examine their professional work, explore and debate conjectures about student learning, and articulate their reasoning and instructional decisions as they acquire and improve their professional knowledge. Therefore, Ball and Cohen (1999) recommend developing innovative ways for teachers "to learn and teach about practice in practice" (p. 12).

Authentic tasks such as the analysis of student work and classroom videos attempt to make connections between professional development and the context of the classroom. Both serve as productive tools for making sense of students' solution strategies, stimulating discussions, and guiding future classroom interactions. Reviewing and

analyzing student work has been endorsed by many researchers (Borko, 2004; Goldsmith et al., 2013; Jacobs, Franke, Carpenter, Levi, & Battey, 2007; Kazemi & Franke, 2003; Kazemi & Franke, 2004; Sowder, 2007) as it allows teachers to deeply investigate their students' mathematical thinking outside the busy and demanding setting of classroom instruction. These activities facilitate meaning and mathematical insight and offer opportunities for teachers to engage with one another, ultimately improving teacher learning (e.g., Birman et al., 2000; Borko, 2004; Desimone, 2009; Garet et al., 2001; Goldsmith et al., 2013; Guskey & Yoon, 2009; Wood et al., 1991).

For example, in the experimental study conducted by Jacobs et al. (2007), teachers collaboratively explored the algebraic reasoning of their students through the use of written student work yielded from their own classrooms. This year-long professional development, which included 89 teachers in Grades 1-5, encouraged teachers to pose problems to their students in the classroom setting and then bring the student work samples to subsequent meetings. The student work served as artifacts of students' thinking and promoted discussions of content and pedagogy. Ultimately, the professional development was found to have a positive effect on both teacher learning and student achievement. The students in participating teachers' classrooms scored better on the written mathematics assessments than students in the classrooms of nonparticipating teachers. Participating teachers demonstrated a significant level of relational thinking, a stronger understanding of the equal sign, and were more likely to generate strategies students might use to solve open number sentences. Researchers found that by

collectively focusing on students' mathematical thinking through the use of written student work, teachers learned ways to support their students' mathematical thinking.

Similarly, Kazemi and Franke (2003) found the use of student work to be beneficial to teacher learning in that it offered opportunities for teachers to learn together in professional development. For one year, thirteen elementary teachers met monthly at a school in cross-grade meetings. Throughout the year, the teachers posed similar mathematical problems to their students and brought the student work to the teacher workgroup meetings. Researchers found that the examination of student work provided opportunities for teachers to discuss their confusions and uncertainties about student reasoning, mathematics, and classroom practice. By collectively making sense of student-generated strategies, teachers explored student reasoning as well as complex mathematical ideas, deepening their own mathematics content knowledge.

Another type of professional development found to promote collective participation and learning is video clubs. In their work with video clubs for example, Sherin, Linsenmeier, and van Es (2009) found that teachers increased their capacity to notice and attend to student mathematical thinking by viewing and analyzing videos of their own lessons. The video club which included seven teachers from the same school met for an hour ten times over the course of one school year. The video clips shown during the meetings were from the seven participating teachers' classrooms and were intended to enhance teacher discourse around student thinking. The researchers purposefully selected clips that were authentic, similar to the teachers' settings, and provided a problematic situation for reflection. This encouraged teachers to attend

closely to student thinking by listening to and interpreting students' mathematical ideas. The findings illustrated that the video clubs served as learning communities that inspired productive discussion of mathematical thinking and provided opportunities for teachers to collectively reason about student thinking and the mathematical ideas in the lesson. They were able to capture the richness of the classroom while simultaneously providing a sheltered time and space for teachers to critically reflect on particular aspects of teaching with one another.

The establishment of learning communities supports teachers' generative growth and reorganization of their instructional practices (Franke et al., 2001). Well-functioning communities offer ideal contexts for teachers to explore new insights and instructional practices (Wenger, 1998). These collaborations allow teachers to interact with common problems, participate in activities embedded in their daily work, engage with student reasoning, and develop relationships with others that push their thinking (Franke et al., 2001; Sowder, 2007; Stein et al., 1999). Learning communities provide safe places where ideas and beliefs can be shared, challenged, and questioned (Cuddapah & Clayton, 2011). They provide opportunities for inquiry, resource sharing, and reflection on classroom practices. Therefore, collaborative participation is essential to effective professional development that aims to improve teacher learning and instructional practices (Cohen & Hill, 2001; Darling-Hammond & Richardson, 2009; Desimone, 2009; Garet et al., 2001; Hill et al., 2013; Loucks-Horsley & Matsumoto, 1999; Stein et al., 1999).

Coherence and Alignment

Teachers learn in professional development that is coherent and aligned. Therefore, professional development should be linked to other professional development experiences, aligned with school and district goals, and supported by national, state, and district standards and assessment practices (Birman et al., 2000; Darling-Hammond et al., 2009; Desimone, 2009; Elmore, 2002; Garet et al., 2001; Guskey, 2003). Professional development is more effective when it is an integral part of school reform, rather than a set of isolated and disconnected activities (Darling-Hammond et al., 2009). Coherence allows for easier implementation of new strategies and reinforces to teachers that their change will be supported.

Teachers do not function in isolation, but rather in the broader contexts of the school and administrative jurisdiction. Teaching is accomplished collectively by a number of people (Cobb et al., 2003), each contributing to a unique aspect of student learning. Mathematics teachers, coaches, principals, and district curriculum specialists form distinct occupational groups with different responsibilities, obligations, and duties. Operating within these various systems, with diverse groups of people, can be extremely demanding and challenging for teachers, particularly when policies and practices are fragmented and in conflict with each other (Cobb et al., 2003; Cobb & Smith, 2008; Gresalfi & Cobb, 2011). The lack of coherence negatively impacts the effects of professional development, collaboration between teachers, and collegiality between teachers and administrators. Therefore, Cobb and his colleagues recommend that school

systems develop a shared instructional vision for high-quality mathematics (Cobb & Jackson, 2011; Cobb & Smith, 2008).

Jackson and Cobb (2013) describe one example in which professional development was productively coordinated across contexts and role groups in the Middle-school Mathematics and the Institutional Setting of Teaching (MIST) Project. Based on 240 video-recorded lessons, leaders of the district and the research team determined the "launch phase," the portion of the lesson when the task is introduced to students (Stein, Engle, Smith, & Hughes, 2008), to be a high-leverage instructional practice that was not being effectively implemented across the district. As a result, the professional development for teachers, coaches, and school leaders that occurred the following year focused on the launch. This included district pull-out professional development, teacher collaborative time, and the coach's work with teachers. Following the professional development, school leaders observed launches in their schools and provided feedback to teachers, met with mathematics coaches to discuss the observations and ways to support teachers, and attended teachers' collaborative meetings.

Jackson and Cobb's (2013) findings demonstrate the importance of coordinating professional development across contexts and role groups to support teachers' learning and the reorganization of the school setting. By focusing on the same core practice, each community understood and shared similar expectations for classroom instruction. Both the school and district became supportive, rather than conflicting, environments where teachers can develop ambitious teaching practices. Their study supports the claim that

professional development that purposefully attends to alignment and coherence results in improved understanding and enactment of new teaching strategies.

Leadership is important to any new and successful initiative. Guskey (2009) emphasizes this fact by stating "strong leadership has played a crucial role in every successful improvement effort" (p. 231). Researchers have concluded that support from leaders at all levels is important to achieving alignment, the successful implementation of new teaching practices, and teacher learning in professional development (Cobb & Jackson, 2011; Elmore, 2002; Guskey, 2009; Loucks-Horsley et al., 2003). Therefore, it is essential to involve and gain support from all stakeholders (Sowder, 2007) including teachers, administrators, and district leaders. Administrators and district leaders possess considerable expertise in curriculum, content, and effective instructional practices and directly assist teachers in their classrooms as they adapt their skills and knowledge to the needs of their students (Elmore, 2002). Opportunities to interact with experts such as program authors or university researchers also offer teachers a different perspective, facilitate the implementation of new ideas, and create partnerships of support (Guskey & Yoon, 2009; Hewitt, Mullen, Davis, & Lashley, 2012; Little, 1993; Sowder, 2007).

Two recent studies have investigated the role of the principals and district leaders in enhancing the effectiveness of professional development on teacher learning. Heck et al. (2008) described the critical role that principals play in initiating and sustaining change. This longitudinal study involved 18,000 teachers who participated in one of the 48 projects sponsored by the National Science Foundation. Principal support was consistently associated with changes in teacher attitudes and practice. When teachers

believed that their administrator supported their reform efforts, they were more likely to modify their teaching practices. Therefore, principal training and support are considered critical for the successful implementation of professional development initiatives (Heck et al., 2008; Loucks-Horsley et al., 2003).

Another example is the MIST Project, led by Cobb and his colleagues, which focused on the mathematics reform initiatives in the middle grades. After five years of implementation with four large, urban school districts serving a total of 360,000 students, the research team rendered two recommendations regarding the support needed for mathematics teachers to develop high-quality and equitable instructional practices (Cobb & Jackson, 2011; Cobb & Smith, 2008). The first recommendation was that school instructional leadership is necessary for improving the quality of mathematics instruction at scale. Maintaining the view that principals are critical to school improvement efforts, Cobb and colleagues recommended a distributed model of leadership that involves administrators and mathematics specialists and coaches (Cobb & Jackson, 2011). Coaches and principals assume joint responsibility for supporting teachers' instructional improvement and growth. In this model, coaches and district mathematics specialists would be primarily responsible for supporting teachers as they learn new instructional practices. Administrators reinforce these efforts by pressing and holding teachers accountable for improvement. Additionally, it is recommended that leaders communicate instructional expectations and provide teachers with the necessary support to meet those expectations. The researchers concluded that school leaders offered the needed support

and press necessary to improve the quality of mathematics instruction (Jackson & Cobb, 2013).

The second recommendation involved district instructional leadership. The project found it to be critical for leaders in the various central office units to share goals for students' mathematical learning as well as a vision of high-quality instruction. Therefore, it is important for central office leaders to regularly collaborate on the design and implementation of instructional improvement policies. It is also important for district leaders to approach instructional improvement at scale from a learning perspective (Cobb & Jackson, 2011). Leaders recognize that significant learning is required for teachers, coaches, and administrators to achieve the district's vision of high-quality mathematics instruction, and it is the responsibility of the district is to provide leadership and support. Further, they value the mathematics expertise of district personnel and utilize this expertise to support teachers and school leaders.

Therefore, to improve alignment and optimize effectiveness, collaboration between school-based leaders and district-level personnel is essential. Planning and training can capitalize on both perspectives. Leaders at the school level understand critical contextual characteristics and district-level leaders have a broader perspective related to district and state goals. As a result, professional development should involve instructional leaders at all levels and strive for coherence and alignment. This ensures that learning opportunities are connected, coherent, and share clear expectations, ultimately enhancing the impact of professional development on teacher learning.

As this review demonstrates, professional development can lead to learning and changes in instructional practice as teachers collectively engage in professional development communities. These learning communities offer opportunities for teachers to collaborate and establish relationships, reflect and examine their practice, discuss and analyze student work or classroom videos, and provide feedback and support to one another. Furthermore, by creating coherent and aligned professional development communities that involve instructional leaders, teacher learning and instructional practices are more likely to change as a result of this collective participation.

Theoretical Perspectives

Traditional models of professional development often involve short, one-time workshops in which information, instructional methods, or resources are disseminated to teachers. Occurring after school or at off-site training locations, facilitators of the professional development sessions may model skills, demonstrate strategies, deliver content, or share procedures related to the classroom. These types of experiences are based on conventional theories of cognition that assume learning is an individual process of acquisition. Learning is treated as a discrete activity, separate from everyday practice.

However, situated learning theory offers a radically different perspective on learning that counters predominant cognitivist views. First proposed by Lave and Wenger (1991), situated learning theory reconsiders learning to be collective and social rather than independent and isolated. Learning occurs through participation in socially situated practices and is situated and contextually embedded (Lave, 1996; Lave & Wenger, 1991). By actively participating in the world, we shape what we do and who we

are. We develop social communities and construct personal identities by engaging in certain activities with certain people. The following section explains communities of practice as a way to conceptualize learning through social participation.

Communities of Practice

Essential for learning, communities share cultural practices, artifacts and tools, common concerns, and mutual endeavors. Communities of practice "are engaged in the generative process of producing their own future" (Lave & Wenger, 1991, pp. 57–58). Communities of practice are everywhere, including our home, work, and school. They exist in multiple facets of our lives, and we belong to numerous communities simultaneously resulting in multi-membership. At times we may participate as core members, whereas other times we engage in more peripheral ways. These various forms of participation constitute the process of learning and ultimately produce identities (Wenger, 1998). Members learn through the process of becoming a full participant in the community. This process, termed *legitimate peripheral participation*, involves the transition of community members from newcomers to old-timers (Lave & Wenger, 1991). Learning is an evolving form of membership, and members increase their competence through a process of moving from peripheral to full participation in communities of practice. As a result, people change perspectives, master new knowledge and skills, and transform their identities as they become included in a community.

Wenger (1998) characterizes communities of practice as including four interconnected and mutually defining components: meaning, practice, community, and identity. As critical characteristics of social participation, each is essential to the process

of learning and knowing. The following sections will elaborate on these four components of a community of practice.

Meaning. As we experience everyday life, we produce new meanings (Wenger, 1998). Therefore, learning is experience. Meaning is created as we engage and participate individually and collectively in the world. We create meaning through our social relations as we develop a common language. As a result, our discourse reflects our changing ability to meaningfully experience the world in which we live. This constant and active process of negotiation of meaning reflects living and human engagement.

Practice. A community is created by the mutual engagement of its members. People interact with one another and form practices that advance some shared enterprise. They establish norms and build strong interpersonal relationships around their collective efforts. Mutuality involves trust and the ability to meaningfully connect to the knowledge and contributions of others (Wenger, 1998; Wenger, 2000). As a result of time and sustained interactions, members of a community develop a shared practice. Learning is doing. Participants are connected in diverse and complex ways as they mutually engage in action around a common practice. A community must coordinate aspirations, cultivate expertise, work together, and engage productively to achieve its objectives. They share historical and social resources, frameworks, and perspectives that produce a shared repertoire of communal resources. These resources embody the history and perspective of the community and allow members to meaningfully communicate with one another about a shared practice.

Community. Members in a community are interconnected. They are informally bound together by shared expertise and passion in a common pursuit. They are engaged in the collective development of defining the community (Wenger, 2000). As a result, learning is belonging. Communities offer social configurations where we mutually engage in worthy enterprises with others, and we are recognized as competent members by our participation. Community members must continually negotiate meanings as they establish goals of the organization and hold each other accountable for pushing the practice forward. They must connect meaningfully and create relationships with one another, producing shared histories of learning. Therefore, membership in a community involves mutual engagement around a joint enterprise.

Identity. Participation and practice are profoundly linked to identity (Wenger, 1998). Learning is becoming and changes who we are. As we negotiate our experiences in social communities and form communities of practice, we build our identity. Within the context of these communities, we create personal histories of becoming. Therefore, we define ourselves by the groups we belong to, identify with, and are deeply connected to. Identity involves a lived experience of belonging that incorporates the past, present, and future (Wenger, 2000). People define themselves by their practice and participation both within and across specific contexts. Therefore, the ongoing process of identity transformation is distinguished by the renegotiation and reconciliation of multiple forms of membership.

Our identities are transformed as we reconcile our various forms of membership and experience a succession of forms of participation (Wenger, 1998). Trajectories of

participation reflect our journeys within and across communities of practice. They include memories, events, stories, and relationships and incorporate the past and the future into the present experience. Over the course of our lives, we produce multiple trajectories that become part of each other. In the process of building trajectories, our identity emerges.

Boundary Encounters, Practices, and Objects

School districts consist of a configuration of interconnected communities of practice that are mutually engaged in a joint enterprise to improve student learning (Cobb et al., 2003). Teachers participate in these interconnected communities and must negotiate meanings between and within these communities. These different communities imply the creation of boundaries and make it difficult to exchange knowledge across communities. Yet, boundary encounters can help members of two or more communities negotiate meaning. Wenger (1998) characterizes a boundary encounter as the coming together of distinct communities of practice to negotiate new meaning or new practices. One such boundary encounter includes the coming together of the teaching community and professional development community.

In boundary encounters, brokers, boundary practices, and boundary objects assist teachers in developing continuity between communities of practice (Cobb & Smith, 2008). Brokers are people who participate, at least peripherally, in two or more groups. They have access to the perspectives of each group and enable connections and meaning across communities to be developed (Wenger, 1998). They serve as a bridge—translating, aligning, and coordinating practice. Brokers are particularly critical to the

development and achievement of a school district's shared instructional vision. They can connect different role groups and bring coherence and alignment to the district's reform effort.

When boundary encounters are sustained over long periods of time, boundary practices may emerge. Boundary practices are defined as a collective brokering that offers members of different communities "something to do together" (Wenger, 1998, p. 114). They promote collective enterprises where members of different communities negotiate meaning and exchange knowledge. A boundary practice is produced over time by those who engage in it. Wenger (1998) states that learning happens at the boundaries as new ideas develop, old ideas are challenged, and inspiration occurs.

Boundary objects are tools used by members of two or groups that serve to coordinate the perspectives of different communities of practice (Cobb & Smith, 2008; Wenger, 1998). These tools enable coordination, but they do not create a bridge between groups and across boundaries. Instead, they provide communities of practice with communication tools (Cobb et al., 2003). For example, documents such as curriculum frameworks are used by districts to communicate guidelines and recommendations for mathematics instruction. These documents have different meanings and purposes for different groups. Teachers may use the frameworks to pace their lesson plans while administrators use them for accountability purposes. A shared vision of high quality mathematics instruction will emerge more readily when school districts incorporate brokers, boundary practices, and boundary objects to connect the practices of diverse communities (Cobb & Smith, 2008).

Professional development is conceptualized as a boundary encounter between the teaching and teacher education communities. Both communities learn from one another as they negotiate meanings and practices associated with mathematics education. Boundary objects in the professional development are student work samples, classroom videos, frameworks, readings such as books or articles, and mathematics tasks or problems. Mathematics teacher educators and teachers are brokers who make new meanings through participation and generation of boundary practices.

Summary

Wenger (1998) maintains that "it is not easy to transform oneself without the support of a community" (p. 89). Participation within these communities of practice is considered fundamental to social learning (Wenger, 1998). Situated learning theory offers researchers new insights into teacher learning. Recent studies have advocated examining shifts in participation and discourse as evidence of teacher learning (Franke & Kazemi, 2001; Kazemi & Franke, 2004). By evaluating teachers' changing participation in communities of practice, researchers can better understand the ways teachers transform their practice. Therefore, this study investigated teacher learning demonstrated through changes in participation. Participation in the forms of activity, written and verbal discourse, social interactions with others, and personal reflections provided evidence of teacher learning and changes in identity.

Summary and Refined Research Questions

Conceptualizing professional development as a boundary encounter between the research and teaching communities creates opportunities for both communities to develop

shared meanings and practices. Though there is a strong research base on the features of professional development that make it effective and beneficial for teachers, additional research is needed to understand how professional development can support teacher learning of core practices. This study investigated four mathematics teachers' trajectories of participation as they engaged in professional development designed to learn to lead mathematics discussions. By analyzing the teachers' changes in participation, this study provides promising ways for teacher educators and researchers to better understand teacher learning within professional development. Drawing upon my review of literature and theoretical framework, I conclude this chapter by further specifying my initial question with two specific research questions:

1. What are the trajectories of participation of teachers who learned and enacted the core practice of leading mathematics discussions through engaging in mathematics professional development?
2. In what ways are teachers' trajectories of participation similar and different?

CHAPTER III

METHODOLOGY

In this chapter, I first provide a background and justification for the selection of case study methodology to investigate my research questions regarding teacher learning in professional development settings. Next, I describe the background and context of the study, the participants and selection of cases, and data collected. After describing methods of analysis, I conclude the chapter with a discussion of issues of validity and ethics.

Research Design

Case Study Methodology

This multiple case study is a retrospective analysis of the first iteration of a larger design experiment investigating teacher learning of instructional practice in mathematics professional development (MPD). Case study methods provide "an in-depth exploration of a bounded system (e.g., activity, event, process, or individuals) based on extensive data collection" (Creswell, 2012, p. 465) by seeking to understand and explain a particular phenomenon (Hancock & Algozzine, 2011; Yin, 2014). By investigating complex systems, researchers utilize case studies to offer insights and illuminate meanings, potentially advancing a field's knowledge base and improving practice (Merriam, 2009).

Characterizing a case study is the unit of analysis, the case (Merriam, 2009). The object of the study involves intensive analyses of a unit or system bounded by space and time (Hancock & Algozzine, 2011). This bounded system may be an organization, individual, community, event, activity, or program and is marked by defined boundaries (Creswell, 2012; Merriam, 2009; Stake, 1995; Yin, 2014). In order to gain a greater understanding of the selected phenomenon, case study research occurs in its natural setting (Hancock & Algozzine, 2011; Merriam, 2009; Yin, 2014). This allows researchers to make sense of significant contextual factors and complexities pertinent to the case (Stake, 1995; Yin, 2014).

Merriam (2009) identifies three special features that define qualitative case studies. Case studies are particularistic, descriptive, and heuristic. The specificity of focus establishes a case study methodology as particularistic. Case studies are intended to examine a particular situation, event, or program allowing researchers to gain in-depth understandings of a unique phenomenon. Further enhancing understanding and meaning is the thick, rich description of the subject under study. Case studies are characterized as descriptive on account of the complete, literal, and holistic description gained from varied sources of information (Hancock & Algozzine, 2011). This extensive description illustrates the complexities of the situation, portraying the interaction and influence of multiple factors over a period of time. Additionally, case studies are heuristic meaning they illuminate our understanding of a phenomenon. They can expose reasons for a problem, describe the background of a situation, or explain why an innovation succeeded or failed. Case studies can confirm or expand a reader's experience by reinforcing what

is already known or lead to the discovery of new meaning. All of which reveal critical insights and knowledge about a distinct phenomenon.

Case studies are not limited to investigating single individuals or events. Multiple-case designs involve two or more cases bound together by a common characteristic (Merriam, 2009; Yin, 2014). When several cases are described and compared, researchers gain insight and understanding into an issue, phenomenon, or condition (Stake, 1995). Evidence across multiple cases becomes more compelling, and the overall study is considered to be more robust (Merriam, 2009; Yin, 2014). As a result, a multiple-case design was utilized to provide detailed descriptions of four purposefully selected teachers' experiences and participation in the Core Math II professional development. The intent is to examine and illuminate specific factors that impacted the teachers' learning and enactment of the core practice of leading mathematics discussions (LMD). Rooted in context, these case studies will illustrate a more vivid and complete view (Merriam, 2009) of the complexities of teacher learning. In the following sections, I present a description of the background and context of the study and the selection of participants for investigation.

Context

During the 2011-2012 school year, two school districts partnered with a local university in the Southeastern United States to participate in the *Core Math: Supporting the Implementation of the Common Core State Standards Using Learning Trajectories* project funded by three awards from NC QUEST North Carolina's ESEA Title II-A Improving Teacher Quality Grants program (Wilson, Seaman, Abernethy, & Frost,

2010). Mathematicians and mathematics educators from the university provided 120 hours of sustained professional development for 30 teachers at two schools located in the southeastern U.S. The Core Math project was intended to prepare teachers to be more knowledgeable of the content in the new Common Core State Standards for Mathematics (CCSSM) as well as to understand the use of mathematics learning trajectories in the classroom.

At the request of both the teachers and the administrators, the Core Math Project was extended for a second year and took place during the 2013–2014 school year. Core Math II built upon and expanded the work of the Core Math I project, which was intended to provide teachers with content knowledge for teaching the new CCSSM (Wilson et al., 2012). In Core Math II, participants engaged with a newly designed professional development curriculum, which focused on the core practice of leading mathematics discussions in order to support students in engaging with the CCSSM Practice Standards. Central to this work was the collaboration among teachers, school leaders, and university faculty in designing professional learning tasks and experiences to support pedagogical change representative of high-quality mathematics instruction.

Two schools located within rural districts in the southeastern U.S. participated in the original Core Math project that was conducted in 2011. Both of the participating schools were defined by the state as high-need schools and continued participating in the project's extension during the following year. Hillside Elementary School (all names are pseudonyms) served approximately 400 students in kindergarten through fifth grade and had a staff of 62 teachers and administrators. The student population consisted of 49.4%

Hispanic students, 28.6% Caucasian students, 17.1% African American students, and 4% Multi-racial students. It was considered a Title I school with 87% of the students classified as economically disadvantaged. Further, only 30% of students considered proficient in mathematics, and the school did not meet the federal requirements for Adequate Yearly Progress in mathematics in 2012–2013.

McDonald Elementary School was a small, yet diverse, Title I school located in a rural southern school district. It served approximately 420 students in grades kindergarten through fifth grade and has a staff of 44 teachers and administrators. The student population consisted of 38.6% Caucasian students, 35% Hispanic students, 18.3% African American students, and 6.5% Multi-racial students. The number of students classified as low-income include 90.5% of the student population and only 34% were considered proficient in mathematics by state standards.

Results from an analysis conducted by the project's research team indicated that the Core Math II professional development was successful at supporting teachers in adopting the core practice of LMD (Wilson et al., 2014). These findings, as described in Chapter I, suggested that Core Math II was effective at meeting its goals and serves as an appropriate context to investigate teacher learning of instructional practice in a professional development setting.

Professional Development Outline

The Core Math II component of the project provided teachers with 108 hours of in-depth instruction on a core practice of mathematics instruction. The professional development was comprised of three phases described by the project as learning *about*

students, learning *from* students, and learning *with* students (Rich, in preparation). Phase One included 30 hours of traditional professional development in which teachers learned about the core practice of LMD. During the first modules that took place in the summer via a traditional summer institute, teachers participated in professional learning tasks (PLTs) by solving mathematics problems, anticipating how students would respond to mathematical tasks, viewing and discussing videos of students engaged in mathematics discussions, and analyzing student work samples.

The second phase took place at Hillside Elementary School, providing a classroom setting where teachers had access to students in an afterschool program. Consisting of 30 hours (18 face-to-face hours and 12 hours of classroom-based activities), Phase Two allowed teachers to not only continue learning about LMD, it also provided an opportunity for teachers to practice conducting mathematics discussions with the support of the professional development leaders and researchers. Questioning, creating learning targets, making student thinking explicit, launching and designing tasks, and responding to students were topics addressed in the second phase of the professional development.

Phase Three of the project was primarily set in the teachers' classrooms as they worked with their own students. The teachers received guidance and support on the implementation of mathematics discussions during this phase. Professional development facilitators visited classrooms on a regular basis to provide teachers with feedback, answer questions, make recommendations, or suggest alternative instructional moves. In addition, facilitators designed monthly meetings to address the needs of the teachers and

attend to common challenges revealed by the participants or discovered through classroom visits. Phase Three was comprised of 20 contact hours (10 hours face-to-face and at least 10 hours of in-class support). Table 1 provides an outline of the Core Math II Professional Development.

Table 1

Outline of Core Math II Professional Development

Phase	Number of hours	Location	Type of PD
Phase I Summer	30 hours	Off site Whole group	Traditional PD focused on LMD
Phase II Fall	30 hours (18 hours of face-to-face and 12 hours of classroom-based activities)	Onsite (Hillside Elem) Whole group & Small groups with students	Afterschool setting with students Teachers practice LMD with students
Phase III Winter	20 hours (10 hours face-to-face & at least 10 hours in-class support)	Onsite (Hillside & McDonald Elem) Whole group Individualized	In-class support and feedback

Members of the research team included university faculty and graduate students. Higher education faculty members offered support of the project and presence within the school districts. I worked along-side a fellow graduate student as members of the research team. We served dual roles, functioning as both employees of the school districts as well as facilitators of the professional development. I was employed by the school system as a district lead mathematics teacher, and my partner was a director of

elementary education. Additionally, we co-designed and co-facilitated all of the Core Math II professional development sessions.

Selection of Project Participants

This project continued the work of the original Core Math project by involving 13 elementary teachers who were previously involved with the cohort of 30 teachers from Core Math I. These teachers were selected via homogenous sampling based upon the distinctive characteristics of enthusiasm for learning ways to improve mathematics instruction and demonstrating the highest amounts of growth from Core Math I. In order to provide a setting where teacher learning of a core practice could be studied, the participants were purposively selected from the sample of Core Math I participants and determined to have the greatest likelihood of implementing high-quality instructional practices in their classrooms. Seven teachers—one kindergarten teacher, two second-grade teachers, three third-grade teachers, and one fourth-grade teacher—were selected from Hillside Elementary School. Six teachers that included two kindergarten teachers, one second-grade teacher, one fourth-grade teacher, and two fifth-grade teachers were selected from McDonald Elementary School. In addition, two administrators and one instructional facilitator from Hillside Elementary, and one administrator and one lead teacher from McDonald Elementary were involved with the project. The thirteen teachers, instructional facilitator, and lead teacher were financially compensated, receiving a stipend for participation. Table 2 provides a list of the Core Math II Participants.

Table 2

Core Math II Participants

Participants	Hillside	McDonald
	Teachers	
Kindergarten	1	2
First	0	0
Second	2	1
Third	3	0
Fourth	1	1
Fifth	0	2
Total	7	6
	Administrators	
Principals	2	1
Curriculum Facilitator/ Lead Teacher	1	1
Total	3	2

Multiple-Case Design

Selection of Case Study Participants

Purposeful sampling involves the intentional and deliberate selection of participants (Merriam, 2009). The sample of case study participants should provide understanding and insight into the phenomenon under investigation in order to maximize learning (Stake, 1995). To best answer my research questions, I selected four teachers that participated in both of the Core Math professional development interventions (two from Hillside Elementary and two from McDonald Elementary) who range in age,

teaching experience, and grade level. This selection ensured that I had maximum variation (Merriam, 2009) and the teachers represented both schools.

Two teachers were selected from each school, one representing the K-2/primary grade span and one teacher representing the 3-5/intermediate grade span. Katherine and Quinn were selected from McDonald Elementary School. Katherine was a Kindergarten teacher with 21 years of teaching experience. Quinn was a fourth grade teacher with three years of teaching experience. Based on the beginning of the year (pre) and end of year (post) IQA results, Katherine and Quinn were selected because they made the highest growth over the two grade spans. In the K-2 grade span/range (primary), Katherine made the highest growth (difference of 14 points, scores changed from 18 to 32 points). In the 3-5 grade span/range (intermediate), Quinn made the most growth (difference of 12 points, scores changed from 16 to 28 points). Additionally, Katherine represented a teacher with more experience (21 years of teaching experience in the classroom). Quinn represented a new teacher with less experience (only 3 years of teaching experience in the classroom). Table 3 provides a summary of the criteria used to select two participants from McDonald Elementary School.

Danielle and Carol were selected from Hillside Elementary School. Danielle was a second grade teacher with seven years of teaching experience. Carol was a third grade teacher with 19 years of teaching experience. In the analysis of the IQA results, three teachers made the greatest gains from the pre and post observations—Danielle (difference of 20 points, scores changed 10 to 30), Nicole (difference of 11 points, scores changed from 26 to 37), and Carol (difference of 3 points, scores changed from 24 to 27).

Table 3

Selection of Case Study Participants from McDonald Elementary School

Teacher	Grade	Years of experience	BOY IQA	EOY IQA	Difference
Bethany	Kindergarten	29	7	20	+13
Katherine	*Kindergarten*	*21*	*18*	*32*	*+14*
Victoria	Second	17	21	24	+3
Quinn	*Fourth*	*3*	*16*	*28*	*+12*
Beth	Fifth	3	28	37	+9
Heather	Fifth	3	21	32	+11

Danielle was selected as a primary teacher and Carol as an intermediate teacher for the study. Nicole was not selected due to her involvement in another professional development opportunity (graduate school at another university). Nicole's participation in the graduate program conflicted with the Core Math PD instructional philosophy and prohibited Nicole from attending Phase Two/Three afterschool professional development sessions. Additionally, Danielle represented a teacher with less than ten years of experience (7 years). Carol represented an experienced teacher with over 19 years in the classroom. Table 4 provides a summary of the criteria used to select two participants from Hillside Elementary School.

Table 4

Selection of Case Study Participants from Hillside Elementary School

Teacher	Grade	Years experience	BOY IQA	EOY IQA	Difference
Sarah	Kindergarten	14	22	21	-1
Valerie	Second	8	23	23	0
Danielle	*Second*	*7*	*10*	*30*	*+20*
Kara	Third	3	25	26	+1
Kelly	Third	6	21	21	0
Carol	*Third*	*19*	*24*	*27*	*+3*
Nicole	Fourth	15	26	37	+11

Data Collection and Analysis

The following section provides a detailed description of the data sources that were used to investigate my research questions focusing on teachers' participation in the Core Math II professional development. Additionally, I describe the methods that were used to analyze these data.

Data Sources

A case study involves the in-depth study of a bounded system, characterized by the selection of a specific time and place and extensive data collection (Creswell, 2012). I took a qualitative approach to investigate four teachers' participation in the Core Math II professional development over one school year, creating a multiple-case design study. Qualitative methods including analyses of interviews, video recordings, and teacher reflections through journal entries were used to describe teachers' participation in the

professional development setting. These data sources were generated and collected during the ongoing analysis phase or implementation of the professional development.

Interviews. Semi-structured interviews (Creswell, 2013; Merriam, 2009; Shank, 2006) were conducted at the middle and end of the project. Each participating teacher was interviewed in February at the mid-point of the project by members of the research team. At the conclusion of the MPD in June, each teacher completed an online survey and participated in a focus group interview. During the focus group interviews, teachers were split into two groups and interviewed collectively by the professional development facilitators. Both the mid-year and final focus group interviews were recorded using a video camera and were transcribed for data analysis.

When designing the questions for the semi-structured interviews and survey, I considered my research questions and focused specifically on the Core Math II professional development. The interview questions were predetermined, carefully created to be open-ended yet focused on addressing the research questions. While the questions were created prior to the interview and planned in a deliberate order using interview protocols (see Appendixes A, C, and D), interviewers were also flexible, responsive to the interviewee, and adaptable to the teachers' responses during the interview process. This allowed the interviewers some latitude to insert questions, ask clarifying questions, and change the order of the questions if needed.

The semi-structured interviews consisted of six to ten questions and focused on the teacher's experiences in the Core Math II professional development, their understanding of the core practice, and their membership and participation in the

professional development community. Different types of questions were employed during the interview to learn about the teachers' experiences, feelings, and opinions of the professional development (Merriam, 2009).

Video recordings. Video recordings are the second source of data for the study. The Core Math II professional development met for one week during the summer before school began, approximately once a month throughout the school year, and for one week in June at the conclusion of the school year. All of the professional development sessions were videotaped. Four professional development sessions, three representing the early stages of the professional development and two representing the later stages of the professional development, were selected for analysis. Four of the videos represented professional development sessions that took place with the whole group. The fifth video recording occurred as each teacher watched and debriefed a mathematics lesson with the MPD facilitators. Using Powell, Francisco, and Maher's (2003) model for videotape analysis, I viewed and described the four selected portions of video data in order to identify and transcribe "critical moments." These critical moments were defined by episodes in which the four selected teachers participated in the professional development activities and demonstrated learning related to LMD. Once the critical moments were identified, these portions of video were transcribed, coded, and used to create a narrative of these four teachers' participation in the professional development.

Journals. The third data source was teacher reflections submitted through electronic journals. Throughout the professional development, teachers were asked to respond to several writing prompts (see Appendix B). These reflections were assigned

periodically in order to obtain teachers' existing understandings, interpretations, and challenges in leading mathematics discussions as well as to assess the impact of the professional development. These journal entries were kept electronically through CourseSites, an online course management system, and teachers were given time during the professional development to respond.

Analysis

Two stages of analysis, within-case analysis and cross-case analysis, were utilized to analyze data in this multiple-case design (Merriam, 2009; Miles, Huberman, & Saldaña, 2014). The within-case analysis was first completed to analyze the teachers' participation within the mathematics professional development and used to create detailed descriptions of the four teachers' trajectories of participation. After completing the within-case analysis, I conducted a cross-case analysis in order to compare the similarities and differences of the teachers' trajectories of participation. The next sections will provide details of both the within-case and cross-case analyses.

Within-case analysis. Initially, each of the four purposefully selected teachers was treated as a single, bounded, and comprehensive case (Merriam, 2009; Miles, Huberman, & Saldaña, 2014). I began my analysis by completing a within-case analysis of each case. This allowed me to describe, understand, and explain the individuals' participation in the Core Math II professional development and ultimately develop a complex and detailed trajectory of participation (Creswell, 2009).

For each case, I followed Creswell's (2009) process of data analysis. I began by organizing and preparing the data for analysis. I color-coded the transcripts to identify

episodes of participation, marking each teacher's discourse with a different color. I also created electronic as well as a paper folder for each teacher to house the data sources generated and collected throughout the process. As the data were being transcribed and organized, I proceeded to read through the data in order to obtain a general sense of the information and reflect on its meaning. At times, I reviewed the video recordings to check the accuracy of the transcripts, clarify statements, or gain an overall impression of the episode.

During the next stages of analysis, critical moments from the professional development, participant interviews, and journal entries were analyzed using my theoretical perspective. Using the etic perspective, pattern codes were created based on theoretical constructs (Creswell, 2009; Maxwell, 2013; Miles, Huberman, & Saldaña, 2014). I used a set of predetermined, overarching codes derived from Lave and Wenger's (1991) theory of communities of practice in order to understand teacher learning. As characteristics of social participation necessary to the process of learning (Wenger, 1998), meaning, practice, community, and identity were utilized to analyze teacher participation. In what follows, I will describe and provide examples of how I operationalized each code.

Meaning. According to Wenger (1998), as we experience everyday life, we produce new meanings. Learning is experience, and meaning is created as we engage and participate individually and collectively in the world. Episodes of the teachers' discourse were coded with the meaning label when they reflected current or new understandings related to the core practice of leading mathematics discussions (LMD).

This included statements addressing the purpose, mechanics or aspects of implementation, and conceptions of LMD.

For example, the following episode was coded as "meaning." It reflected the teacher's understandings of the intent and purpose of LMD.

> How can I teach a child to fully understand a certain math concept and move him/her even farther? Let the kids discover math or solutions on their own. As a teacher, the reflection aspect of teaching has taught me a great deal. It has allowed me to change the way I teach certain standards that are more appropriate to the kids learning style. Also being more flexible and not worrying about answers whereas the process is what matters for understanding.

Practice. People in a community interact with one another and form practices that advance some shared enterprise (Wenger, 1998). Participants are connected in diverse and complex ways as they mutually engage in action around a common practice. Learning is doing. Episodes of discourse were coded as "practice" when they addressed enactment with students. The teachers described their current or past experiences in the classroom specifically related to the leading mathematics discussions. This included reflections on their successes and challenges of enactment as well as attitudes regarding implementation.

The following example was coded as "practice." In this episode, the teacher was open and honest about her attempts to enact the practice of LMD in her classroom. She disclosed her areas of weakness and described her efforts to change her teaching practices.

> That is probably my weakest area. What to do with, you know, what to ask them and how to get them talking. And with the kindergarteners it kind of depends on

> the day and it depends on what you're doing. It seems like there are some days that we have great discussions and they're really good with it. And then there are other days where they're just not going to talk at all. . .That was just the discussion part is the hardest part for me as far as trying to get them, trying to get it to be more student centered. I mean that's just a whole flip for me and it's something that I definitely see the value of and I think that they're headed that way but we're just going to keep working toward it.

Community. Communities offer social configurations where we mutually engage in worthy enterprises with others, and we are informally bound together by shared expertise and passion in a common pursuit (Wenger, 1998). Members in a community are interconnected, and learning is belonging. Episodes of discourse were coded as "community" when they related to the professional development community which included teachers, administrators, and instructors. Statements expressed value for learning and collaborating with peers, receiving support from one another, and connecting and creating relationships with others. For example, in the following statement, the teacher appreciated the community for providing the support she needed to enact the practice of LMD. She valued the collaboration and support that the community offered. Therefore, this episode was coded as "community."

> I enjoy being able to come and not just talk with people in my school but talk with people from another place who are dealing with the same things I am because we don't get that opportunity a lot even at a district level. We don't get the opportunity to talk from teachers, to teachers from other schools to see what they're struggling with so it's kind of nice to get to come and bounce ideas and explore together with another set of people. You know being able to have that collaboration is kind of nice.

Identity. Learning is becoming and changes who we are (Wenger, 1998). As we negotiate our experiences in social communities and form communities of practice, we

build our identity. We create personal histories of becoming; and therefore, we define ourselves by the groups we belong to, identify with, and are deeply connected to. Episodes of discourse related to the teachers' identities, competence, and self-perceptions were coded as "identity." This included statements regarding the teachers' confidence as a mathematics teacher, within the MPD, and with the practice of LMD. Accounts reflected their roles as mathematics teachers, and in some cases leaders, both within and outside the MPD.

For example, in the following episode, the teacher demonstrated a lack of confidence in her abilities to lead mathematics discussions in her classroom. She questioned her ability to implement the practice and did not identify with the new model of instruction. Therefore, this episode was coded as "identity." The teacher stated:

> I was really intrigued by how it all seemed to flow. I'm not so intrigued on my ability to make it flow. That's where I, like I love that it works for these people. That's great. It was one of those things where it sounds really well, but I don't know that I could do it yet.

During the within-case analysis, episodes of discourse which included critical moments from the professional development, participant interviews, and journal entries were coded as meaning, practice, community, and identity. Tables, one for each case, were created to organize and display the data. The tables included the episode number and location, the quote or description of the episode, the assigned code, and any memos or notes related to the episode. Table 5 shows an example of the table used to organize the case study data.

Table 5

Example of Data Organization Table

Episode number location	Description of episode Quote	Assigned code	Memos Notes
Episode 16			
PLT Sequence 4: Debriefing Videotaped Lessons Danielle 2:46–8:40 pp. 2–3 Lines: 67–92	Danielle reflects on her discussion during the lesson. She discusses why she selected certain groups of students to share their strategies. Danielle: *I picked the money group because they had . . . my other 2 groups were very similar in their strategies. They found the total of the money he made, the total of the money he lost and compared them. These guys, the first group started with a constant, they started with $70 and then actually manipulated the money and counted it again. So I wanted them to be able to see the actual transfer of money from hand to hand and then how it compared to, what's the word?* MPD Instructor: *Abstract.* Danielle: *So it was more that real world application versus this now abstract way of looking at it.* (Line 92)	• Meaning: Purpose • Practice: Enactment Retelling what happened during the lesson Uses a more concrete strategy to begin the discussion.	Danielle mentions one of the questions she used with students—"Why did you start with $70?" Danielle has been working on questions since the beginning of the MPD (see Episode 2). Evidence of growth?

During the coding process, some episodes were multi-coded. That is, the episode fit into multiple categories and was labeled by more than one code. For example, the following episode was coded using the meaning and practice labels. The teacher stated:

> This is something that I have really worked with my kids on—standing up for themselves if they don't understand something they need to ask questions so that they do understand it because my kids would just sit back and do the oh, yea, okay good, explain it to me. And so you have to make sure that you understand those people. Their math learning is not going to grow if you don't understand

> and you just say that you do. So the conversation has been much better after that going that it's okay that I don't get this because someone is going to help me.

The teacher identified elements of her practice and enactment by describing how she worked with her students on taking responsibility for their learning and asking questions if they did not understand. She also understood a purpose of mathematics discussions to be the clarification of students' misunderstandings and questions, giving students opportunities to learn from one another. Therefore, this episode was coded as "practice" and "meaning." Table 6 provides a summary of the number of coded episodes and multi-coded episodes during data analysis.

Table 6

Number of Coded Episodes during Data Analysis

Teacher	Number of episodes	Number of multi-coded episodes
Danielle	40	27
Carol	49	28
Katherine	28	15
Quinn	75	44

Matrix displays are regarded as tools for displaying, organizing, and analyzing data (Maxwell, 2013; Miles, Huberman, & Saldaña, 2014; Yin, 2014). Defined by rows and columns, matrices display data in an organized, tabular format. They enable the researcher to collect and arrange data for quick viewing, reflection, comparison, and analysis. After collecting and coding the data, I created a matrix display for each case. The matrix included four rows labeled with each participation code and two columns

marked by the early and late phases of the professional development. This allowed me to combine and summarize data for each case and thus, analyze the single cases in depth. Using this visual display, I was able to notice trends and patterns across the phases of the professional development and themes began to emerge. I recorded the themes in four descriptive outlines.

At this point in the data analysis process, I was able to generate a detailed description of each teacher's participation over the course of the MPD (Creswell, 2009). Using both the matrices and descriptive outlines, I created a descriptive narrative for each case to illustrate the teachers' trajectories of participation. Each case narrative will be presented in Chapter IV.

Cross-case analysis. Following the analysis of each case, I completed a cross-case analysis in order to compare the four teachers' trajectories of participation. The intent was to provide a deeper understanding and explanation of teacher learning in MPD. By examining the similarities and differences across the four cases, abstractions and generalizations can be constructed and transferred to similar professional development contexts (Merriam, 2009; Miles, Huberman, & Saldaña, 2014).

Within the cross-case analysis phase, I employed the case-oriented approach (Miles, Huberman, & Saldaña, 2014). A case-oriented approach utilizes a comparative analysis of a small number of cases. Once the analysis for each individual case has been completed, similarities and associations are identified. Cases with different outcomes are compared in order to form general explanations. The results are specific, concrete, and historically grounded patterns.

My study consisted of four different cases and examined the participation of each teacher within the context of MPD. After each narrative was constructed, a meta-matrix was created to systematically compare the four cases. Each teacher's participation was compared using the four characteristics of social participation. Both commonalities and differences across cases were analyzed in relation to meaning, practice, community, and identity. As I re-read the cases and the meta-matrix displays, I noted patterns that began to emerge. I particularly noted patterns among the cases with similar outcomes. For example, three of the four teachers attained full membership in the MPD community. I was especially interested in the commonalities among these three teachers. Further analysis, which included re-reading the cases and matrix displays as well as discussions with the research team, allowed me to note differences in the participation of the fourth teacher and to form explanations for why her trajectory never led to full membership in the MPD community. By analyzing the patterns, themes emerged across the cases and a final narrative detailing the similarities and differences across the cases was composed.

The within-case analysis of the four cases yielded four distinct trajectories of participation. The cross-case analysis allowed me to compare similarities and differences across the four cases. The final narratives and findings will be shared in Chapter Four.

Reliability and Validity

Maxwell (2013) defines validity as "the correctness or credibility of a description, conclusion, explanation, interpretation, or other sort of account" (p. 122). In order to strengthen the validity of my research, I incorporated several techniques including intensive, long-term involvement with the project, providing rich data, and triangulation.

Observations were contextualized, prolonged, and repetitive over an 11-month period. As both the researcher and professional developer, I attended the professional development meetings conducted each month and recorded field notes of the discussions and activities conducted. In addition, I periodically visited the school sites, walked through classrooms, attended planning meetings, and conducted informal conversations with teachers. By adequately engaging in data collection (Merriam, 2009), I gained a deeper understanding of the four participants' experiences in Core Math II. This allowed me to confirm my findings and check my inferences along the way rather than making erroneous judgments about changes in the teachers' learning. The variety of data collection methods, in-depth description, and extensive involvement with the Core Math II project ensured the study's results were reliable, consistent, and dependable.

In order to provide a "full and revealing picture of what is going on" (Maxwell, 2013, p. 126), I collected a variety of rich data sources including interviews, observations of the professional development sessions, and journal entries. The information acquired from these multiple sources provided more convincing evidence for my conclusions (Yin, 2014). This offered opportunities for triangulation in which the data serve to corroborate the findings and bring increased understanding about the case (Merriam, 2009; Stake, 1995; Yin, 2014). Data were cross-checked and compared to ensure confidence in my interpretations and increase internal validity. Additionally, I collaborated with fellow researchers throughout the study to analyze data, compare findings, and validate my interpretations. Investigator triangulation further enhanced the study's credibility and trustworthiness (Merriam, 2009; Stake, 1995).

Subjectivity and Potential Ethical Issues

My role as a lead teacher in the school district caused me to become interested in mathematics professional development as a researcher. My primary goals were to research professional development and examine how teacher learning could be impacted. This research focusing on professional development was extremely important to me as a district leader, professional developer, and researcher. It has the potential to influence the way that I work with teachers, develop and create professional development materials, and continue my work as a scholar. Therefore, I approached this topic with passion, urgency, importance, and necessity. With this elevated level of dedication and commitment, I needed to be aware of my personal biases toward my research topic. I wanted to be open to the data that I have collected. It was important to keep my biases in check and be candid and straightforward about my feelings towards teacher development as I pursued my research interests. Therefore, I utilized investigator triangulation, involving others to assist me as I collected and reviewed my data (Merriam, 2009; Stake, 1995). This helped to ensure that I accurately recorded and portrayed the results.

Another factor that I considered throughout the project was my job title. While my position as a district lead teacher offered me access to a large population of teachers, I needed to also be aware of the power that the position afforded. I did not want teachers to feel pressure to participate in my research or falsely represent their true feelings and experiences based on our working relationship.

I also believed that my school district offered teachers a great deal of high quality professional development and this continued with the extension of the Core Math project.

I am interested in how the participants perceived the MPD and how it influenced their learning to lead discussions in their classrooms. Therefore, I did not want to influence any of the responses or portray the teachers' experiences in a more positive or negative light than was intended. I wanted to be cautious about analyzing data that were collected in my own district and interpret these findings accurately. As I collected and reviewed data, I carefully searched for examples and counter-examples of participation, teacher learning, and changes in instructional practices. Negative or discrepant case analysis, caused me to purposefully look for variation (Merriam, 2009). By intently searching for examples of ways teachers express evidence of learning and enactment, I did not miss or overshadow additional findings that emerged from the data. In addition, I did not want to portray teachers in undesirable or negative ways. I had a commitment to represent teachers in positive and strength-based ways. My goal was to focus on positive changes in teachers' learning during professional development.

CHAPTER IV

FINDINGS

The primary purpose of this study was to better understand four teachers' learning whose practice of leading mathematics discussions (LMD) changed as a result of engagement in mathematics professional development (MPD). The intent is to describe the teachers' trajectories of participation through an analysis of changes in their discourse related to the purpose of LMD, their enactments in the classrooms, the support of the PD community, and their own competence with LMD. Two specific questions guided the research: (a) What are the trajectories of participation of teachers who learned and enacted the core practice of LMD through engaging in MPD? and (b) In what ways are teachers' trajectories of participation similar and different?

In this chapter, I first describe four mathematics teachers' trajectories of participation. The following descriptions will demonstrate how the teachers' participation changed as they engaged in the MPD, illustrating an advanced understanding and enactment of the core practice of LMD. Finally, I will conclude my findings by comparing the teachers' trajectories of participation and illustrate the similarities and differences across cases.

The Case of Danielle

Danielle was a second grade teacher from Hillside Elementary with seven years of teaching experience. From the beginning of the MPD, Danielle's engagement suggested

she joined the community with the prospect of becoming a full participant. This was evidenced by her initial participation. Episodes from the professional development will describe she entered the community as an active, willing, and receptive participant and provide insight into her early understandings of LMD related to meaning, practice, community, and identity. As the MPD progressed, Danielle consistently engaged and her enactment of LMD evolved as she refined her understanding and meaning of the core practice. By the conclusion of the professional development, she had established connections between the MPD and teaching communities, resulting in aligned purposes and improved enactments of LMD. Her full participation in the community was marked by competence. In what follows, I provide holistic snapshots of Danielle's participation early in the MPD as well as an analysis of her participation to serve as a baseline for her trajectory of participation that ultimately led to full participation (Wenger, 1998).

Initial Participation

From the start, Danielle participated actively in the mathematics professional development. She contributed to discussions, engaged in problem-solving tasks, interacted with small groups to compare solution strategies, analyzed student work samples, shared her own challenges, and provided a window into her practice for other teachers. The following episodes will illustrate Danielle as an eager and engaged participant who valued collaboration and support from the community.

On the second day of the summer professional development, participants interacted as small groups to solve the Buying a Horse Problem: *A man buys a horse for $50. He sells if for $60. He then buys it back for $70. Then he sells it one last time for*

$80. How much money, if any, did he make or lose on his trades? Danielle collaborated with four other teachers to solve the problem. During the interaction, she explored the reasoning of others and demonstrated a value for her colleagues' alternative solution strategies. When working with her small group, Danielle made multiple comments and posed a variety of questions that led the group to their solution, such as, "Can I see yours? I'm a visual. I understand yours though. Yea. When I look at it, I can understand it. You did it differently than me but . . ."

Danielle not only contributed to small group discussions, she also interjected during discussions with the large group. During whole group discussions, she was willing to ask and answer questions, share her opinions and viewpoints, and describe how her group solved various mathematical tasks. For example, Danielle's contribution in one whole group discussion focused on comparing various solution strategies and the analysis of student work samples. In another instance after reflecting on their problem solving process and analyzing their mistakes in small groups, Danielle readily volunteered and explained a common error her group experienced when solving the problem in whole group discussion:

> When we looked at the 70, I forgot if that was the adding or subtracting 70. He bought it for 70 so there was subtracting 70 and what they did was they took that money that he had earned, that bonus money and just nixed it like it negated everything that happened before it. So then the last transaction when he earned $10, well that's it. He has 10 extra dollars.

Her comments were echoed by several other group members as they explained the confusion with the multiple money transactions. Her contribution brought attention to

the most difficult part of the problem—the transaction in which the man buys the horse back for $70. She opened the conversation by candidly sharing her error and visibly exposing her challenges with the task. As the discussion proceeded, the group recognized the importance of establishing a safe classroom environment in which mistakes were valued as learning opportunities and the value of discussing mistakes with their students.

Later in Phase One, participants analyzed several student work samples of the Horse Problem. One strategy, involving negative numbers, caused debate among the group members. Some felt like it was difficult to understand and would only cause confusion if presented to elementary students. Danielle related to the student work that was presented, and she boldly admitted that she solved the problem in a similar way. She stated:

> That one makes perfect sense to me. That's how I did it. Well I get, when I do this one, I didn't do the negatives, I just kept track of that's what he spent . . . He spent $120. I didn't do negatives at all. I didn't put the negatives in there. Yea I said that they spent $120.

She was able to identify and describe important mathematical ideas and make connections between solution strategies. The preceding episode demonstrates Danielle's willingness to share and contribute to discussions throughout the MPD, even when the ideas contradicted the popular opinions of the large group.

Across Phase One, Danielle participated actively in the MPD community. To better understand her learning of LMD, I use the following examples to demonstrate the way Danielle talked about the meaning and purpose of the practice, the enactment of the

practice in her classroom, the MPD community support for her learning, and her competence with the practice early in the MPD.

Meaning. As she participated, Danielle demonstrated a broad and general understanding of the purpose and instructional moves associated with leading mathematics discussions. For example, her journal response at the end of Day 7 illustrated that she valued group work in the mathematics classroom. In her words, group work allowed her students to "learn from each other," "feel comfortable," and "look at problems differently." This illustrated that she valued a variety of solution methods as well as students talking and working together to solve problems. In an early journal response, she wrote,

> I have worked very hard to create a student-centered learning environment this year. We talked about our norms and how everybody is important to the group because we can learn from each other. We have done a lot of group work as well, especially in math, so they are very comfortable with it. We also do number talks almost every day so students can see that even though we look at a problem differently, we can still arrive at the same answer.

For Danielle, the practice of LMD served to promote group work as well as an appreciation of varying solution strategies. Her initial statements, such as these, reflected broad and general understandings of the purpose of LMD.

Practice. From the beginning of the MPD, Danielle discussed her practice and the ways she attempted to enact mathematics discussions in her classroom. Danielle was willing to share both her successes and challenges of LMD. She was open and honest about the difficulties of enactment and publicly lamented over her personal struggles with engagement, collaboration, questioning, and student ownership in the classroom. For

example, in an early journal response during the first phases of the professional development, Danielle wrote:

> One challenge that I have is that I don't have 100% engagement. Even if it is a high demand tasks I have students sign off. We have talked about the mathematical learning practices but that has not seemed to help certain students. They have also tried to work more independently versus really working together. I think I would like to have jobs for people until they can create the jobs on their own. It seems that the independence throws them. It may be because they have always had two teachers all day and they just wait for somebody to help them without attacking the problem on their own. Whatever the case may be, we need to solve it.

Danielle described her initial attempts at leading mathematics discussions in her classroom. She portrayed a true and accurate representation of her enactment, was able to reflect on her practice, and expound on several struggles with implementation. However, the instances focus more on generic practices such as collaboration and engagement. She remained positive and sincere as she expressed the need to solve each issue, but she only offered one solution and attributed students' lack of perseverance to their past classroom experiences.

Community. From the beginning of the MPD, it was apparent that Danielle valued learning mathematics in a community. This was evidenced by her interactions with her peers as she solved mathematical tasks and candidly discussed her challenges with enactment. Danielle valued her colleagues in analyzing teaching and instructional practices, specifically those related to leading mathematics discussions. In the following episode for instance, Danielle pointed out the specific questions Erin, instructional facilitator from Hillside Elementary, used to help her group members solve the

mathematical task. She used this as a learning opportunity and reflected on her own questions. On Day 2 of the summer professional development, Danielle summarized the discussion she had with her small group as they solve a mathematical task by saying:

> We talked a lot about getting stuck after the first question. My question was what numbers were you looking at in the problem? Show me where you proved that part. So they would prove where they had 48 legs but then they had 22 animals and not 17. But where I was stuck is I assume that they're going to get that when I ask that question, but what do I do when they don't? Yea and Erin, she broke her questions down a little more. She would say ok, how many legs do you have? How many are in the problem? How many animals do you have? How many animals are in the problem? Ok, there's where the problem is. What do we do now? So it was very specific versus my broad hey you should get it from what I'm saying because it's wonderful but you don't.

Through acknowledging the ways Erin's questions helped her understanding, Danielle communicated her value of the community publicly.

Identity. During the early stages of the MPD, Danielle eagerly and confidently engaged in problem solving tasks, shared her solution strategies, and participated in small and large group discussions. However, the same confidence she portrayed as a learner did not extend to her classroom or her teaching. When discussing her classroom, she often focused on her challenges with implementing mathematical discussions. She expressed concern and apprehension when examining her questioning techniques and abilities to promote perseverance, independence, and engagement among all of her students as they solved and discussed mathematics problems. One such instance occurred during the summer institute. Participants watched a video of a class of third grade students solving a challenging mathematics problem. The video focused on the whole group discussion in which the teacher facilitated the sharing of three different

solution strategies. One strategy was especially difficult for the rest of the class to interpret and understand; and therefore, became the focus of the mathematics discussion. As the MPD participants analyzed the video, Danielle made the following comment:

> The amazing thing to me is that she didn't necessarily spend the time there, the kids did. I don't get this, I don't understand why you did this part of it, and then poor little Marlin, I mean, 20, 25 minutes later, he's still, I don't get it. And there wasn't eye rolling, there wasn't (sigh), you know, Marlin, again. I know, poor Marlin, I felt so bad for him, but he stood up for himself and it wasn't an embarrassment and it wasn't just oh yeah, I get it let's move on. It was I want to get this so that I can do it and I thought that was crazy. Like, I've never seen anything like that in any of the classrooms I've taught in.

She seemed perplexed, yet in awe of such a lengthy, deep, and supportive classroom discussion despite the fact that she had participated in similar discussions during the MPD. While Danielle experienced and valued such discussions for herself as an adult learner, she questioned her ability to achieve them in her own classroom. She was unable to identify herself as a teacher capable of LMD.

Later Participation

Initially, as Danielle experienced professional learning tasks (PLTs) in the MPD setting, it became evident that she valued mathematics discussions for herself as a learner. In solving mathematical problems and interacting with groups to discuss and compare possible solution strategies, Danielle had opportunities to participate in mathematics just as her students would. These experiences influenced both her appreciation and understanding of the practice over the course of the MPD.

As the MPD progressed, value shifted from Danielle as a learner to Danielle as a teacher. Danielle began linking that value of these practices to her own teaching and to

her own students. In one survey, she stated, "The more I showed my students that I was still learning and it was hard for adults, the more they were willing to take risks." The early opportunities that allowed her to experience mathematics in student-centered ways were the same types of opportunities she wanted to create for her students. The following episodes will demonstrate that Danielle respected the time it took to implement and facilitate mathematics discussions and appreciated the long-lasting results that developed as a result of implementation.

Danielle openly acknowledged that LMD was challenging. It took time and student achievement results did not immediately change as result of implementation. She stated, "But that's the important part. It happens over time. You don't see it right away." In a final survey, she wrote, "Facilitating discussion does not happen in a week but is a continuous process." She recognized, yet revered, the practice of LMD as a process that "happens over time." Danielle realized that the benefits were well worth the extra effort and instructional time. She described her students' experiences by saying:

> It's also challenged the children because they don't just sit there and take a back seat to their learning. They can't just like get it through osmosis they have to be active and take part and engage in it so that is a huge challenge coming up from teachers that don't do this kind of teaching. They have to re-learn how to learn. But it's good, it's a good challenge.

Danielle attributed mathematics discussions to her students' improved learning and engagement. As a result of implementation, her students were more actively engaged with the mathematics, challenged by high level authentic problems, and able to take responsibility for their learning. Students did not "take a back seat to their learning" but

instead took an active role in the learning process, ultimately leading to improved confidence, agency, and independence in mathematics.

In another interview, Danielle described her class's renewed excitement around mathematics. As a result of implementing mathematics discussions, her students were more engaged, excited, and interested in problem solving. The class became so involved in mathematics lessons that they often lost track of time. She described such instances by saying:

> There have been so many times that we have math at the very end of the day. It's the last thing that we teach after recess which is a little crazy to get them back on track but there were many times that I look up and I'm like oh no, we've gotta pack up. And I am shoving my children out the door. Because math runs so long and they were all engaged and they were all excited about it. Apparently I was as well and oh no, what if we miss the bus! But up until really this year I never had that. I was always, okay well yep now math is done now let's get transition over here. I was very on time. But now I'm late every day. It is a good thing. It's not me constantly looking at the clock.

Danielle's statements indicate that she valued the core practice of LMD for herself as well as her students. Although challenging and time consuming, mathematics discussions were important to Danielle. She recognized the benefits they offered for her own learning as well as her students' learning.

Throughout the MPD, Danielle continued to participate in central ways as her trajectory led to full participation in the MPD community. Her participation was marked by deepened understanding of leading mathematics discussions that was more aligned with the purposes advanced in the PD, episodes of reflection, specific and targeted descriptions of her lessons and instructional moves, and increased confidence due to the

support she received from the community. As the following episodes demonstrate, Danielle became a full participant in the mathematics professional development.

Meaning. Danielle's understanding of leading mathematics discussions developed throughout the professional development. She became more focused on the mathematical goals of her lessons and how her instructional moves advanced these learning goals. Danielle was able to describe her practice with clarity and specificity, demonstrating a deeper understanding of high-quality mathematics teaching. As her understanding of the practice deepened, her instructional moves became more focused and purposeful.

The following two samples illustrate that Danielle continued to value group work and assorted solution strategies. In contrast to earlier understandings of the purpose of the practice, Danielle's evolving understanding of the purpose for discussion expanded to include specific mathematical goals such as the comparison of strategies, moving to efficient strategies, and making sense of word problems, real world problems as well as abstract representations. When reflecting on one of her lessons later in the year, Danielle focused on the mathematical goals and learning targets of the lesson:

> My learning target for my kids was basically just making sense of the problem and exploring their math. We have worked tirelessly on word problems, making sense of it. So that was my main focus for them. Yea, exploring their math. So trying different strategies and finding one that they were comfortable with for this problem. Because a lot of them they would start one way, they had this big long number sentence and then they said well I don't know how to do it that way, I'm going to try it this way.
>
> Because that's what we're trying to work on is comparing strategies, seeing the similarities and it's hard. It was hard for them to see that.

In another example, Danielle reflected on the mathematics discussion during the lesson and discussed why she selected certain groups of students to share their strategies.

> I picked the money group because they had . . . my other two groups were very similar in their strategies. They found the total of the money he made, the total of the money he lost and compared them. These guys, the first group started with a constant, they started with $70 and then actually manipulated the money and counted it again. So I wanted them to be able to see the actual transfer of money from hand to hand and then how it compared to . . . so it was more that real world application versus this now abstract way of looking at it.

As these examples demonstrate, Danielle's understanding of LMD and its purpose became more specific and descriptive. She was able to describe the specific learning targets of the lesson as well as her purposeful decisions in selecting and sequencing the students' solution strategies. As her understanding of the practice evolved, her recounts of her instructional moves became more focused and purposeful, and the descriptions of her lessons became more specific and targeted. As her understanding of the practice developed, her enactment of LMD developed accordingly in her classroom. Overtime, Danielle described her practice with clarity and specificity demonstrating an evolved understanding of LMD.

Practice. Throughout the professional development, Danielle made her practice public and was open and honest about the successes and challenges she experienced while leading mathematics discussions. During the later phases of the professional development, Danielle became more clear and specific when reflecting on her enactments of LMD. She pinpointed specific areas of strength and also acknowledged areas of growth and improvement, all of which related to particular aspects of leading

mathematics discussions. She focused on three components that structured her lessons – the launch, explore, and discussion phases – and analyzed her teaching directly associated with each phase. For example, Danielle honestly identified successes and challenges during a lesson as she debriefed with the professional development facilitators. She reflected:

> I'm telling you they struggled and I don't like when my kids struggle, I'm definitely a rescuer. And they were struggling, I'm like oh my god what am I doing? And the second day they said we want to try it again. I figured, it can't hurt and then it was just amazing, amazing to see what they came up with.

Later, she discussed monitoring in preparation for a discussion as a strength of her practice. She stated, "That's something that I feel very comfortable in, is explore. I don't think that I'm too leading, I lead more in the launch than I do in the explore. I'm very much an okay, here and go." In these reflections, Danielle honestly examined her practice with the facilitators and was able to note her strengths. During a professional development that followed this debrief, Danielle described how she worked with her students on taking responsibility for their learning and asking questions if they did not understand. She explained:

> This is something that I have really worked with my kids on—standing up for themselves if they don't understand something they need to ask questions so that they do understand it because my kids would just sit back and do the oh, yea, okay good, explain it to me. And so you have to make sure that you understand those people. Their math learning is not going to grow if you don't understand and you just say that you do. So the conversation has been much better after that going that it's okay that I don't get this because someone is going to help me.

By taking responsibility of her students' learning, she improved students' collaboration within small groups, increased engagement and interest in mathematics for herself as well as her students, and helped her students take more responsibility and ownership for their learning.

At the end of the MPD, Danielle openly shared about her practice of LMD. Her descriptions of her practice noted particular strengths and the challenges she had experienced.

Community. As the professional development progressed, Danielle's value of the MPD community as a support for her learning and teaching continued to grow and expand. She became more reliant on the community for support in leading mathematics discussions in her classroom. She acknowledged the importance of having support from her colleagues, the MPD community, her administrators, as well as the professional development instructors. This support allowed her to manage and overcome challenges as she led mathematics discussions and faced criticism from her peers.

For example, during a Phase Three session, Danielle shared the importance of having administrators in the professional development by stating, "From a teacher's prospective, it's really nice that we have our administration come in and hear about this stuff and understand when they come in our room that we're not just having a free for all." She later expressed appreciation for her administration being involved in the professional development by stating in the focus group interview, "Well that's one good thing about our administrators being part of this. They did get that and they do understand where others, if your principal is not on board and doesn't understand."

Both in the focus group interview as well as the final survey in June, Danielle acknowledged the support she received from the professional development community. This included support from Marie and Deneen, the MPD facilitators. She stated,

> We just melded so well together back even with the break. We could do it because we've gone through everything. And we all have strengths and weaknesses so an area that I was really having a hard time with I could come to the group and say this is falling apart on me and other people would say oh well I tried this and I did this and I did this and this worked for me. So it gave me many more ideas because that was something that was struggled with.
>
> The third phase where we did it with our kids because I was learning, I was doing it with my students so I had a vested interest in what was going on in our room and that support. You know, I could call on somebody else that I was teaching with or Marie and Deneen were fantastic at coming in and giving immediate feedback, this is what worked, this is what didn't work, this is how you need to change it up next time.

In the final survey, Danielle wrote,

> It has been great to have other people support you through struggles that you may be having while trying to implement core math in your classroom. The support from Deneen and Marie has been outstanding. The feedback was immediate and very helpful. I also enjoyed the camaraderie between the two schools. I could go to anybody in Core Math II and knew they would listen to what I had to say and give suggestions.

In these reflections, Danielle attributed her learning of LMD to the community's support and guidance. This support allowed her to manage challenges as she worked to enact the practice and helped her grow as both a teacher and a leader within the MPD and school communities as the next section will demonstrate.

Identity. As a result of the professional development, Danielle gained confidence both as a teacher and an instructional leader. As she made her practice public in the

professional development community, she also shared her experiences with her school grade level team and with teachers throughout her school district during a district-wide professional development conference for elementary teachers. She became a confident and competent member of the community who shared her practice beyond the mathematics professional development. In the final survey, she stated:

> I feel that I have participated fully. I have brought my difficulties, successes, and problem-solving ideas to the group. I, with another core math teacher, have presented student centered instruction as professional development in my district. I have opened myself up as a teacher and, in turn, grew tremendously.

In the focus group interview, Danielle described her interactions with her grade level team:

> Other people on our team were very, very difficult. I had a veteran teacher on my team and I had a first year teacher. First year teacher was more willing to try some things but didn't understand it and they had so many other things playing into being a first year teacher that it was a little overwhelming so it got cut. And I get that, I understand that. The veteran teacher, she had been teaching for so long and it worked for her that she couldn't see the value in what we were doing even talking through lessons and inviting her to come to our classroom and observe. It was just, oh no no that's good for you but I'm going to stick with what I'm comfortable with. That was very, very frustrating.

As these reflections show, Danielle's confidence in enacting the practice and the competence she felt within the MPD community led to a new identity as a broker with her school and district communities.

Summary of Participation

Danielle's initial participation, marked by eagerness and reflection led to full participation in the MPD community. Through consistent engagement, openly sharing

her successes and challenges as she enacted the practice, and through community support, she was able to align meanings of the practice and improve her mathematics discussions in her teaching. Her full participation in the community led to increased confidence and competence, resulting in connections between the MPD and other communities.

The Case of Carol

Carol, an elementary teacher for 19 years, set herself apart from the MPD community by establishing herself as a veteran teacher. She used such phrases as "back in my day," "I'm old school," "us veteran teachers," "as the veteran, old teacher," and "I'm old and so I've seen everything come full circle." Throughout the MPD, she continued to make it clear that she was different from the other participants, pointing out she was an outsider based her age, experience, and teaching style. Therefore, Carol's participation was initially characterized by misalignment and inconsistency. Although an active and receptive participant, Carol lacked confidence and struggled with enactment. She valued the practice of mathematics discussions, but found it difficult to implement. She considered the MPD and teaching communities to be disconnected and found it difficult to align the practices associated with LMD with those of her current teaching. In Carol's own words, she summarized her struggle by saying, "How do we get to that point with the kids?"

As the MPD progressed, the value she experienced as a learner and participant during mathematics discussions transferred to her students. Invested in the purpose and intent of the MPD, Carol became committed to the gradual process of growth and change. Significant support from both the MPD and school communities allowed Carol to

renegotiate her identity and overcome challenges with enactment in order to achieve full participation. The following analysis of her participation will describe this trajectory and the factors that motivated her to reach full participation. Episodes from the professional development reveal Carol's understandings of LMD characterized by meaning, practice, identity, and community.

Initial Participation

From the outset, Carol participated actively and energetically in the MPD. She was a lively and spirited participant who often interjected comments, questions, and even jokes. She enthusiastically engaged in PLTs, collaborated with others to solve mathematics problems, willingly answered and responded to questions, and contributed to both small and whole group discussions. Additionally, as a teacher with 19 years of experience, Carol readily imparted classroom stories and anecdotes, offered connections to the classroom, and suggested instructional strategies. She was kind, caring, and supportive of others, often affirming members of the group as they shared a solution method or expressed a challenge.

Several episodes during the first days of the Summer Institute indicated that Carol appreciated opportunities to collaborate with others. She valued the contributions of her colleagues and seemed genuinely interested in how they solved problems. For example, on the second day of the MPD, Carol collaborated with four other teachers to solve the Buying a Horse problem: *A man buys a horse for $50. He sells if for $60. He then buys it back for $70. Then he sells it one last time for $80. How much money, if any, did he make or lose on his trades?* As Carol interacted with her group members, she frequently

interjected questions and comments such as, “What did you do? What did you get? Oh wow. I never would’ve went that way. This makes sense to me. Yours makes sense to me more than the way they figured it out.” In order to move the group forward, she highlighted areas of agreement and disagreement by saying, “But we all agree on that first step. What gets us is when he starts buying things back.” and “Okay we all agreed that this part. The problem starts after he sells it for $60. From that point on none of us agree.”

Carol’s encouragement and affirmations extended to whole group discussions as well. When another group of four teachers explained a different strategy for solving the Horse Problem in which they started with a larger amount of money, Carol declared, “See I never would’ve gone with that original big chunk of money. I never would’ve thought of that.” In a second instance, a teacher admitted that she used an incorrect strategy to solve the Horse Problem. Carol comforted her by saying, “But yours makes so much sense to me though. I mean really. It really did. Even though mine made sense to me the way I did it.”

All of these episodes reflect Carol’s positive interactions with the MPD group. She valued opportunities to collaborate with others, participating both as a student and a learner. She used such opportunities to analyze and compare solution strategies and reflect on her own mistakes and problem solving methods. It is apparent that she appreciated the different mathematical strategies shared by her colleagues and was willing to explore the reasoning of others, even when it was different from her own.

During the pre-enactment stage of the MPD, Carol participated actively in the MPD community. Her participation revealed an initial understanding of the core practice of LMD. The following examples will demonstrate the way Carol talked about four aspects associated with her understanding of LMD: meaning, enactment, competence, and community support.

Meaning. Carol's participation demonstrated a consistent, yet broad and general, understanding of LMD. She recognized LMD as a way of supporting student learning, which she viewed as "process" over answer. For example, on the second day of the MPD, following a discussion of solution strategies for the Ostrich and Giraffe problem, the teachers reflected on their past experiences as mathematics students and ways they were taught problem solving. Carol interjected, "Just as far as how things really have changed, back in like my day it was really all about the answer. Now days, it's all about the process." Carol's comment not only suggests a realization that mathematics instruction has shifted, but also implies her initial understanding of LMD as a process, not overshadowed by an emphasis on the correct solution.

Carol's statements revealed that her initial meaning of the practice included two particular characteristics: collaboration and multiple solution strategies. For example, her journal response at the end of Day 7 illustrated that she valued group work in the mathematics classroom. She wrote, "A student centered classroom is a classroom filled with movement, noise and learning. They are usually working in groups of four or with a partner. I hear discussions between two or more people, not just one person talking."

Carol described the mathematics classroom as one filled with noise and movement and pointed out that learning takes place as students work with partners or small groups.

Additionally, the response illustrated that she valued a variety of solution methods. She continued to write:

> Their discussions have led to some interesting and puzzling solutions. Behavior has improved and so has their verbalizing what they have done or do not understand. It is okay that they don't always have the same way to solve a problem or not any solution. I want them to be able to show me the process.

Carol understood that discussions offer opportunities for students to work together and share various solution methods. Once again, she returned to the importance of students showing their process for solving mathematics problems. It is evident, by statements such as these, that Carol's initial meaning of LMD reflected a broad and general understanding involving process, group work, and multiple solution strategies.

Practice. While it is evident that Carol strongly valued the practice of LMD, she found the enactment of LMD to be more challenging. From the beginning, Carol candidly shared her struggles with implementation. She explained that it was difficult for her to shift from being teacher-directed to student-centered. She openly admitted that she had issues with being impatient, too leading, and overly talkative during classroom discussions. For example, during a whole group discussion following the Horse Problem, Carol reflected on her experience of interacting with the other participants as they solved the problem. She stated,

> I think a lot of the way we question, the problem is, is how do I say this, our question is to get the answer we want to hear or is it the answer that we should be

> hearing because I think that's the problem for me. It's how can I get them to really to say that 20 is the answer. I mean that's where my problem I think is because I'm so impatient sometimes.

In the reflection and throughout the early stages of MPD, Carol honestly shared her difficulties with enacting LMD, including being impatient at times. She pointed out that her questions were often too leading, intended to get students to the correct answer. Her actions were contrary to the meaning she espoused. She understood LMD to be a process, placing value on collaboration and multiple solution strategies. However, when enacting LMD, Carol acknowledged using questions to quickly lead students to a correct answer. She claimed to value mathematics as a process, yet enacted opposing instructional moves.

From the outset, Carol was willing to make her practice public by openly and honestly describing the difficulties she faced in enacting LMD. Despite her years of teaching experience, she did not claim to be an expert in the practice. She was sincere and truthful during episodes of reflection and candidly shared her struggles with shifting to high-quality instructional approaches.

Identity. Carol's interactions with peers during the MPD and her accounts of the classroom reflected an appreciation for multiple solution strategies. During the early stages of the MPD, Carol often affirmed her group members when they offered a unique solution or strategy for solving a problem. Similarly, she described her students' solutions as "interesting" and "puzzling," asserting, "It is okay that they don't always have the same way to solve a problem." However, Carol did not express the same value for her own mathematical skills during PLTs. At times she questioned herself and

displayed a lack of confidence in LMD. For instance, as Carol interacted with a small group of teachers to solve the Horse Problem, she occasionally uttered statements of confusion and frustration. Examples included: "I am so confused right now." "Oh, we agree so far. And then I'm lost." "I'm just confused." "See I can only get to the part where he sells it for 20 and then I'm so, I'm confused even though I figured it out." "It's not working." Despite the fact that Carol solved the problem correctly, she lacked confidence in her own abilities. She questioned her mathematical skills and quickly became frustrated when she could not arrive at a quick solution. The value Carol espoused for her students and teammates was not the same value she shared for herself.

Community. From the beginning of the MPD, it was apparent that Carol valued learning mathematics in a community. This was evidenced by the positive interactions with her peers as she solved mathematical problems and candidly discussed her challenges with enactment. Carol made it clear that she valued the contributions of others and appreciated opportunities to collaborate with the group. For example, after the group brainstormed ways to prepare for LMD by anticipating student responses, Carol adamantly declared, "That's why I like collaboration."

The community offered Carol support as she solved challenging mathematical problems, examined alternative solution strategies, analyzed student work samples, and explored instructional moves related to LMD. Carol described one instance in which she and a fellow teacher discussed the challenges of anticipation before LMD. Carol stated:

> Valerie and I were talking outside that how hard that anticipation is so perhaps a pre-test on whatever type of skill they give you just a real quick idea how you can anticipate what they might do. That's a hard concept.

This episode illustrated the support Carol received from the community in implementing a new instructional model for teaching mathematics. From the beginning, the group rallied around one another. They felt comfortable discussing their challenges with enactment of LMD and willingly offered suggestions for overcoming such challenges. Carol found the community support helpful and comforting.

Later Participation

Carol remained an active and lively participant throughout the MPD. Though, one notable change in Carol's participation were statements regarding the value of the practice LMD. During the pre-enactment portion of the MPD, Carol indicated that she valued the mathematics discussions for her own learning. She appreciated the collaboration with others as well as opportunities to learn from the unusual strategies and common mistakes. As the MPD progressed, value for LMD shifted from herself as a learner to the students in her classroom. She made it apparent that she found value in implementing mathematics discussions in her own classroom and outside of the professional development setting. She maintained that the practices associated with LMD contributed to students' learning, engagement, confidence, mathematical understanding, and overall success. Both in surveys and interviews, she attributed value to the practice of LMD. She enthusiastically declared, "I think they learn better" and "The kids in my class have enjoyed the way I taught this year. They also seemed to grasp more of the lessons than previous years."

The later stages of her participation in the MPD were marked by minor, gradual changes rather than dynamic, revolutionary transformations. Her understanding of the

practice of LMD remained consistent and she continued to struggle with enactment. However, the MPD community offered her the support she needed to renegotiate her identity and improve her practice. The following episodes will demonstrate that Carol became a full participant in the mathematics professional development, despite her challenges with enactment.

Meaning. Carol began the MPD with a broad and general understanding of LMD as a way of supporting student learning, which she viewed as "process" over answer. Her initial meaning of the practice included two particular characteristics: collaboration and multiple solution strategies. On the second day of the MPD, Carol asserted that mathematics instruction should focus on the process, not the answer. She reiterated the same sentiment on the last day of the MPD by stating, "not worrying about answers whereas the process is what matters for understanding." After being involved in the MPD for a full year, Carol remained committed to the same meaning and purpose of LMD.

The following samples illustrate that Carol continued to value students' learning process, cooperative group work, and various ways to solve problems. Her understanding of LMD remained consistent and unchanged. Later in the year when reflecting on one of her lessons, Carol stated:

> This is so important to me. I think that they have to understand what they're trying to do . . . And I'm really to the point now the end result I'm not even that, if the answer is right because I really need them to understand what to do and why. So there's a lot of these they're off by a few but I mean we're just trying to focus and figure out I'm asking the process.

Carol reiterated the same sentiments in responding to surveys and interviews. She described her students' progress by saying, "But they're getting much, much better as far as oh she doesn't just want a product anymore. She wants to see how I'm solving this, how I figured it out." Similarly, during the last days of the MPD, Carol reflected on what she had learned during the MPD by saying:

> How can I teach a child to fully understand a certain math concept and move him/her even farther. Let the kids discover math or solutions on their own. As a teacher, the reflection aspect of teaching has taught me a great deal. It has allowed me to change the way I teach certain standards that are more appropriate to the kids learning style. Also being more flexible and not worrying about answers whereas the process is what matters for understanding.

Additional statements reflected Carol's attention to cooperative group work and collaboration. She stated,

> We're here to, you know, work together to figure out what the problem is or how you guys can solve it and so we're getting better so I'm hoping for when they move up to next year that this is like you know they're so used to doing this cooperative grouping.

Each of these examples demonstrated Carol's broad and general understandings of LMD remained consistent throughout the MPD. Her initial meaning of the practice, characterized by a value for process over answers, collaboration, and multiple solution strategies did not evolve or change. Her early understandings of the practice were identical to her final understandings – resulting in a fixed and established meaning of LMD. While this interpretation may first seem negative, it is quite the contrary. Carol's unwavering and steadfast understandings became the bedrock for her beliefs and values.

Because she strongly valued the practice of LMD, she was willing to enact the practice in her classroom, even when she found it difficult and challenging.

Practice. From the beginning, Carol openly discussed her struggles with enacting the practice of LMD. The shift from traditional, teacher-directed mathematics instruction to a student-centered approach proved to be exceptionally challenging for Carol, a veteran teacher of 19 years. In her reflection statements, she recognized that she was often too leading and talkative during discussions. She found it difficult to facilitate discussions, listen without interrupting, and allow her students time to struggle productively with mathematics problems. Although driven by good intentions, she frequently interjected during her students' small and whole group discussions and tried to simplify tasks by providing step-by-step instructions to guide them to a correct answer. During an afterschool meeting in which the Core Math group Carol shared her successes and challenges with implementation by stating:

> You know the hard part for my class is they're good as far as working together, they're good as far as you know trying to understand what they have to do and then that's the hard part because then we have the highs, we have the lows and you know they're all trying really, really hard which I'm thrilled at. But we need to be able to, it's a constant, I'm trying to pull, pull, pull and I wish I had more of that from them and not me.

On another occasion, Carol reiterated her struggles as she debriefed a mathematics lesson with the professional development facilitators. She admitted, "I don't know if I should have said that because I gave away that it's a (multi)step problem." She went on to say, "I really have to listen to how I phrase things or what I'm, because I know I can be very leading. And I know I hate that. And I just keep yapping and I need to be quiet."

While Carol found enacting the practice of LMD to be challenging, she embraced the change. She valued the practice for both herself and her students. She described it as "inviting," "career changing," "welcoming," and "encouraging." Furthermore, she felt the practice contributed to her students' improved engagement, learning, and mathematics success. In reflecting on her Core Math experience, Carol asserted:

> And just as the veteran old teacher that I love this. I mean I love the change. I'm done with that standing up in front of the room stuff. I think that it's about time the kids do the work. I've done that for years, the you know, but I welcome the change as far as the kids.

Carol summarized the benefits of implementing the practice of LMD by saying, "It's encouraged me, it's encouraged that through me you know the kids have succeeded so I more than welcome a change."

Implementing the core practice of LMD was not easy for Carol. She readily admitted and described difficulties she faced in enacting LMD. She recognized that she struggled with a new instructional model for teaching mathematics and battled with shifting to such an approach. However, such a change did not discourage her. Instead she welcomed the change and appreciated the process of growth and improvement.

Identity. During the pre-enactment stages of the MPD, Carol displayed a lack of confidence. She questioned her mathematical skills during PLTs, became frustrated when she could not quickly arrive at a solution, and was hesitant to argue or defend her own strategies. When presented with a challenging task, Carol would often respond with a witty remark, declare statements of confusion, or even renounce the task altogether. During one PLT, she admitted, "That's where my problem I think is because I'm so

impatient sometimes." Carol's impatience was not directed towards others, but rather with herself as a student or learner.

However, over the course of the MPD, Carol's participation reflected a position of growth and learning. She realized that changing her practice was an ongoing and gradual process that took time, support, and patience. She reflected on her experience by saying, "It's more of a gradual process. I have not mastered anything as of yet but that's an ongoing process." She developed patience with herself and allowed herself the space to learn and grow at her own pace with her own students. In one interview, she expressed appreciation for opportunities to learn alongside her students. She stated,

> I think that's really helped but as time has gone on since we've been doing this quite a bit, we do a lot of tasks now, good or bad I know. And if it's bad we just try to redo it and figure it out together. You know? I think that's pretty much what we're figuring it out together, the kids and me.

By the end of the professional development, Carol was able to integrate particular aspects of LMD into her current practice and adapt to the needs of her students. In the final days of the MPD, she commented, "So I think you just have to get used to whatever is right for me, what works for me, for my class, what works for my kids." Carol gained confidence in herself as she gradually enacted the practice with support. She developed an appreciation for the learning process which led to a new identity of continual growth within the MPD community.

Community. In order to enact a new model of instruction into her classroom, Carol relied on support from both the school and professional development communities. This support came from her grade level team, the teachers in the Core Math community,

as well as the professional development leaders. Carol clearly welcomed and accepted the support from her communities, by stating, "Nothing better than learning from your peers."

With community support, Carol was able to experiment with mathematical tasks, ask questions, and discuss challenges with implementation. She described the value of working with her grade level team to incorporate high-level, engaging mathematics problems into their weekly lesson plans. The team of four teachers collaborated to find engaging problems for their students. They met regularly to reflect on their successes and challenges of implementation and make changes to their upcoming mathematics lessons. She valued her team's willingness "to give it a try."

Additionally, Carol acknowledged the importance of having support from the MPD community. This support allowed her to manage and overcome challenges as she led mathematics discussions in her classroom. For example, at the conclusion of the MPD, Carol participated in a focus group interview with four other participants. She shared her appreciation for working with teachers in different grade levels and opportunities to discuss common concerns with implementation. She stated:

> You're second (pointing to another teacher in second grade), I'm third but a lot of your stuff say if it didn't work, it more than likely didn't work or something similar that I could relate to whatever you were going through so that makes things easier for all of us.

Carol also recognized the professional development instructors for offering support and guidance. She expressed gratitude for the instructors' availability to answer questions and provide feedback. She expounded:

> You guys (referring to the PD facilitators) were more than willing to help us figure out if we weren't doing it right or how can I fix it, how can I cut this out and do whatever I'm supposed to. So that was really a plus I think. And the expectation wasn't, it was just for our success and you were there to help us with that so if I fell I could just pick myself up and get back up or if I didn't understand it I would definitely ask.

She went on to say:

> I think that's made a big difference as far as you and Deneen being available. I think that really has because I could email Deneen anytime I wanted to. Just something real, even if it was stupid to me you know but then again no questions, so. But I really think that made a big, big difference you being available for us.

Carol's learning can largely be attributed to the community's support. Initially, Carol struggled with implementing the practice of LMD. She found enactment challenging. It was especially difficult to change and overcome traditional instructional moves that were considered teacher-directed rather than student-centered. However, support from the school's administrator, grade level team, school-level instructional facilitator, as well as the members of the MPD provided Carol with the encouragement and assistance she needed. Such support was significant, contributing to both her identity and change in practice.

Summary of Participation

Carol's initial participation transitioned to full participation with the support from both the school and professional development communities. Despite challenges with enactment, Carol remained committed to the purpose and intent of LMD. She valued the practice for both herself and her students and persisted in the continuous process of growth. Community support led to connections between the MPD and her current

mathematics instruction, allowing her to renegotiate her identity as a traditional mathematics teacher and overcome challenges with enactment.

The Case of Katherine

Katherine was a Kindergarten teacher with 21 years of teaching experience from McDonald Elementary School. Initially, it was difficult to determine if Katherine joined the community with the intent of becoming a full participant. This was due to her lack of observable participation. While active and willing, attending every professional development session, Katherine rarely participated in whole group discussions or publicly discussed aspects of her classroom instruction. Marked by marginal participation, evidence of learning could not be established. However, dynamic shifts took place during the later stages of the MPD. Katherine identified with her students as learners, transferring value for herself as a learner to her students. As this shift in value occurred, it led her to participate in her home community in a different way. She realized that she had something to contribute to her school as well as the professional development community. Therefore, she began to position herself differently. Katherine moved from being a reserved participant to one that confidently shared a more integrated understanding of LMD with her colleagues by making her own practice public for others (and herself) to learn. Despite her lack of participation in the early stages of the professional development, Katherine later felt like she had something to say that was meaningful, signaling her confidence with LMD. Ultimately, Katherine became a full participant in the community. The following analysis will illustrate Katherine's transformative trajectory that led to full participation in which her initial non-

participation in the MPD problematized and enabled connections between communities and resulted in aligned purposes for LMD, improved enactments of LMD, full participation in the MPD, and competent status in MPD.

Initial Participation

Katherine was a willing and eager participant. She attended every session of the MPD and actively engaged in the PLTs. She collaboratively solved mathematical problems within small groups, collectively watched videos of mathematics discussions, and planned lessons with fellow Kindergarten teachers. However, an absence and lack of observable participation characterized Katherine's initial involvement in the MPD. There were very few instances where she participated in the whole group discussions. She was very reserved, rarely participated, and remained silent for the majority of the professional development sessions. When she did talk, she described how she solved a problem (after being prompted by the instructor), made a joke about a problem involving crickets, and offered recommendations for how a teacher could have modeled one strategy for students. Katherine did not open up or publicly share her teaching practices.

On the second day of the summer professional development, participants interacted as small groups to solve the Buying a Horse Problem: *A man buys a horse for $50. He sells if for $60. He then buys it back for $70. Then he sells it one last time for $80. How much money, if any, did he make or lose on his trades?* Katherine willingly collaborated with several teachers to solve the problem. After participants had an opportunity to solve and discuss the problem within small groups, several individuals were asked by the MPD instructors to share their solution strategies. Deneen invited

Katherine to show and explain her work to the large group. Katherine agreed and proceeded to explain:

> Okay so basically what I did was I said okay he started with he spent the $50. When he sold the horse for $60 he made $10 and he sold it again for $70, he lost $10. When he sold it for $80 he made $10, so he had $10. And then I just kind of left it at that. And then when they all, when they started talking about it and I said well you know that's not right, that's not enough so then Erin asked me how I got it and when she asked me how I got it well then I started thinking a little bit more. But I asked her to show me what she did and what she showed me made sense.

Katherine did not volunteer to share, but once elicited by the PD instructor, she was able to describe how she solved the problem to the whole group. Katherine also acknowledged the assistance she received from her teammates and how this helped her arrive at the correct answer.

On a separate, but rare occasion, Katherine contributed to a discussion that involved an analysis of one teacher's instructional moves. During the MPD, participants watched a video of a class of third grade students solving a challenging mathematical problem. The video focused on the whole group discussion in which the teacher facilitated the sharing of three different solution strategies. One particular strategy involved a number line in which a student displayed increments of time. Following the video, participants examined the student strategies as well as the teacher's facilitation moves. Katherine offered a suggestion to make the student thinking more visual to others. Her recommendation was to ask the student to circle a portion of the number line. She advised,

> At least say show me where to circle. Even if they had done that it'd be more visual rather than just something they said but it was visualized even if she had said it just to that child, show me.

The previous two examples illustrate the few times that Katherine participated in whole group discussions. While she attended every session of the MPD, she often remained silent. Her participation was marked by few episodes. She was a reserved, yet willing and cooperative participant.

Katherine remained a passive and quiet participant during the early stages of the MPD. The following examples, although minimal, will be used to demonstrate Katherine's learning of LMD. They will illustrate the way she talked about the meaning and purpose of the practice, her competence and enactment of the practice in her classroom, and the MPD community support for her learning.

Meaning. Early in the professional development, Katherine demonstrated that she understood the purpose of LMD was to promote collaboration, engagement, and independence among students in the mathematics classroom. She clearly valued students talking and helping one another. One journal response illustrated that she appreciated opportunities for her students to "work together to find solutions to problems," "explore ideas," and "learn to value ideas from their peers." She wrote,

> In a student-centered classroom, there is a lot of discussion among the students as they work together to find solutions to problems. The teacher facilitates by asking questions, which provokes thought and helps the students stay motivated. Students explore ideas and learn to value ideas from their peers as well. They learn to depend on their skills rather than expecting the teacher to have all the answers.

Katherine defined the role of the teacher and the student during mathematics discussions. While students are exploring, working together, and learning from one another, the teacher acts as a facilitator that asks thoughtful questions and encourages students to remain engaged and motivated. Katherine also highlighted two benefits of mathematics discussions: creating independence and generating appreciation for other's ideas and contributions.

While it was evident that Katherine valued discussion, her purposes for discussions were related to the interaction with peers rather than the mathematics that students were learning. She initially viewed discussions as serving non-mathematical goals such as learning to work together and valuing ideas from peers. What was absent from Katherine's early exchanges were descriptions of what students were learning as a result of these discussions. She focused on broad and general goals such as motivation and collaboration rather than content-specific objectives.

Practice. It is difficult to describe Katherine's early enactment of the practice. Katherine did not share publicly about her teaching practices. She did not share personal stories related to her own classroom or discuss successes and challenges with implementation.

The previous journal response illuminated the initial meaning Katherine made of the practice. Although it did not describe Katherine's current enactment, the response did elude to her understandings of the practice and her role in enacting the practice. She wrote:

> In a student-centered classroom, there is a lot of discussion among the students as they work together to find solutions to problems. The teacher facilitates by asking questions, which provokes thought and helps the students stay motivated. Students explore ideas and learn to value ideas from their peers as well. They learn to depend on their skills rather than expecting the teacher to have all the answers.

In this instance, Katherine explained that the teacher facilitates discussion by asking questions. The intent of asking questions was to provoke thought and help students stay motivated. Katherine described the teacher's role during discussions in very general ways. She did not describe specific techniques that teachers utilize to orchestrate discussions or implement high-quality mathematics instruction. This short response may offer some evidence of Katherine's enactment in her own classroom. She was seemingly implementing discussions with her students and encouraging her students to work together and value one another's contributions.

Community. While Katherine was silent and reserved during whole group discussions, she willingly participated in small groups to solve PLTs, discuss classroom videos, or plan mathematics lessons with her peers. Although quiet, she was an active member of the community that valued opportunities to learn and work with others. She respected her colleagues and appreciated their assistance.

Early in the professional development, Katherine noticed the value of learning mathematics in a community, as evidenced by her interaction with Erin (instructional facilitator) and Heather (school lead teacher). During one PLT, involving the Horse Problem, Katherine collaborated with Erin and Heather to solve the task and share solution strategies. Katherine found the task to be especially difficult and initially arrived

at an incorrect solution. In the following episode, Katherine talked about how Erin helped her discover the correct answer for the problem. She explained how working with others was useful in her own learning and attributed her solution to assistance from others. She stated,

> Okay so basically what I did was I said okay he started with he spent the $50. When he sold the horse for $60 he made $10 and he sold it again for $70, he lost $10. When he sold it for $80 he made $10, so he had $10. And then I just kind of left it at that. And then when they all, when they started talking about it and I said well you know that's not right, that's not enough so then Erin asked me how I got it and when she asked me how I got it well then I started thinking a little bit more. But I asked her to show me what she did and what she showed me made sense.

The community offered Katherine support as she solved mathematics problems and struggled to find correct solutions. Katherine valued the community for such support and collaborative interactions.

Identity. Katherine's lack of observable participation may be attributed to her lack of confidence. Early in the professional development, Katherine assigned competence to members of the community rather than herself. When discussing how she solved the Horse Problem, she contributed her success to others. She talked about how Erin helped her arrive at the correct solution for the problem. She shared,

> . . . so then Erin asked me how I got it and when she asked me how I got it well then I started thinking a little bit more. But I asked her to show me what she did and what she showed me made sense.

Katherine did not rely on her own competence to participate. Instead of trusting herself, she depended on the competence and support of others during the MPD. Katherine did

not identify as a mathematics student or a reform mathematics teacher. This is evidenced by her lack of participation. She did not discuss her classroom practice or openly share her experiences during the early stages of the MPD.

Later Participation

Although willing and engaged, Katherine was quiet and reserved during the first stages of the MPD. She rarely participated or contributed to whole group discussions. She understood mathematics discussions to promote broad and general goals, placed confidence in others rather than herself, and did not share aspects of her classroom enactment. Katherine's later participation was marked by dynamic shifts – shifts in participation, enactment, and understanding.

Initially, Katherine did not openly discuss her teaching or instruction in the classroom. Later in the professional development, she shifted to making her practice public, candidly sharing her strengths and challenges. Katherine opened up and began to willingly discuss her enactment of LMD. She shifted from being very quiet and private to being reflective and responsive, eager to make her practice public. She openly shared her strengths and challenges in implementing a new model of teaching mathematics and sincerely reflected on her enactment in the classroom.

For example, during a debriefing session with one of the MPD instructors, Katherine reflected on one of her videotaped mathematics lessons. As they watched and discussed the lesson, she carefully examined her progress and willingly admitted areas of strength and growth. In the following episode, Katherine admitted that she struggled with introducing mathematics problems to her students. She shared,

> I don't know if that's long enough, if I need to give them more information or if that is enough information for them. Or if I should've led into that a little bit better instead of just saying okay, this is what we're going to do. I've tried to cut back because I tend to give them more information than they actually need to do it. And so I've already worked it for them before they go back to their seat. So what I've been trying to do is give less and I think maybe that's, I think that's why maybe I feel like sometimes it's weaker than it should be because I'm not giving as much support as I would have given maybe before.

It is evident that Katherine grappled with her role in launching and setting up mathematics problems. While she realized it was better not to lead students or provide them with too much information as she introduced the problem, she found it difficult to relinquish control and provide less support. She was able to verbalize her struggle as well as her efforts to transform her current instruction. This was a vast change from the beginning of the MPD where she never discussed her classroom or admitted challenges she encountered during enactment.

As the session continued, Katherine disclosed that discussions were especially difficult for her, admitting they were her "weakest area" and "hardest part." She struggled with student participation and moving to a student-centered approach to teaching mathematics. She stated,

> That is probably my weakest area. What to do with, you know, what to ask them and how to get them talking. And with the kindergarteners it kind of depends on the day and it depends on what you're doing. It seems like there are some days that we have great discussions and they're really good with it. And then there are other days where they're just not going to talk at all. . .That was just the discussion part is the hardest part for me as far as trying to get them, trying to get it to be more student centered. I mean that's just a whole flip for me and it's something that I definitely see the value of and I think that they're headed that way but we're just going to keep working toward it.

In each of these episodes, Katherine was open and honest about her attempts to enact the practice of LMD in her classroom. She disclosed her areas of weakness and described her efforts to change her teaching. Her statements demonstrated that she struggled with integrating a new model of instruction with her existing one. She confirmed, "…that's just a whole flip for me." However, there is a clear value for LMD and student-centered approaches. She was determined to transform her instruction and enact the vision of the community, admitting "we're just going to keep working toward it." The next sections will illustrate how Katherine became a full participant as her meaning, enactment, identity, and community involvement became more aligned with the MPD.

Meaning. Katherine's initial understanding and purpose of discussions were very broad and general. At first, she valued discussions for developing non-mathematical attributes such as collaboration and an appreciation for other's ideas and contributions. Her early exchanges were related to the interaction with peers rather than the mathematics that students were learning. Later, Katherine became more focused on the mathematical goals of her discussions and how the discussions were intended to advance these learning goals. For Katherine, the purpose of the discussion shifted from generic goals such as working with peers to more specific, mathematical goals such as learning about the addition of doubles and how to measure and sort. This was evidenced by her statements as she debriefed one of her mathematics lessons with a MPD instructor. She explained why she selected the numbers for the problem in the lesson by saying:

> We've been working on the doubles and so that's, we went with the 4 and the 4 because last week before we did 5 and 5. And so we've just been working with

> the doubles and have been wanting them to see we've already done flipping it like if you have a 3 and a 4, that 4 and 3, 3 and 4 is the same thing.

Katherine was very intentional in the numbers she selected for the problems and her mathematics discussions. These numbers were directly related to her learning targets and addressed content-specific goals associated with the addition of doubles and the commutative property.

Katherine continued to describe other classroom discussions. She was pleased with her students' engagement and participation as they compared measurements and sorted objects. She stated,

> When we were doing measurement and they were comparing towers to see which one was longer and which one was shorter and being able to tell each other why it was longer and why it was shorter, they were great with discussing with that. When we did the, we had a little thing where they had different kinds of snacks and they did a sorting activity with it and I just basically gave it to them and I said okay sort this. And then they had to discuss how they had sorted it. They did great with that.

These episodes demonstrated a shift in purpose and meaning for Katherine. Instead of focusing on non-mathematical goals such as the collaboration and interactions with peers, Katherine shifted to recognizing how discussions contribute to deep mathematics learning. She acknowledged that discussions can advance a specific mathematical goal, and in turn, became more purposeful and selective in the numbers and activities she incorporated into her mathematics lessons.

Katherine continued to value discussions throughout the MPD. However, this value expanded beyond non-mathematical goals merely related to peer interactions. She

understood that discussions can serve to advance both mathematical and non-mathematical goals. In the next episodes, she explained that discussions serve to help her students with language and social skills. Additionally, she recognized her students' mathematical improvements as a result of discussions, improvements specifically related to number sense. She stated,

> I mean a lot of them come in they don't have language skills anyway. Even the English speakers they don't have a lot of skill with talking to someone. So I think it's a whole big learning process with kindergarteners. They're not just learning about numbers, we're learning how to talk to each other and do that too. I do think their number sense really plays with, umm, they're a lot further with their number sense than my other kids were at this time last year. So I do see with that there has been a great help that way.

In another interview, Katherine concluded that her students' mathematical understanding and confidence improved due to the discussions she was facilitating in her classroom. She proudly declared, "I can see how it has helped my students not only to be able to talk to each other about math but it's helped them understand more and to feel more confident in what they're doing." She recognized improvements in mathematical understanding for all of her students. She maintained, "I think my kindergarteners this year have a lot better understanding of how numbers work than they have in past years. Even the ones that struggle still have a better understanding . . ." During the interview, she went on to claim that students "were understanding numbers better" and were able to explain and model such understandings. She stated,

> Students are getting a better background and they're getting more number sense and that they're understanding numbers better. That it's not something that, it's something that carries over into other things because when you're doing that

> discussion and they're learning how to talk to each other and share their ideas back and forth and that's something that translates into other areas as well. It's not just that we're learning to put 2 and 2 together and make that 4 but they're learning to be able to tell somebody why they think that 2 and 2 is 4 and explain that not just well, because you have 2 and 2 and it's 4 but to be able to take some manipulatives or draw a picture and explain it and show it.

In her statements, Katherine recognized both mathematical and non-mathematical purposes for LMD. She maintained that her students acquired social skills such as learning how to talk to one another and improved their number sense and mathematical understanding. She extended her value and understandings related to the meaning and purpose of discussions from generic goals to more specific, mathematical goals. This shift resulted in meaningful learning for her students as well as herself.

Practice. Initially, Katherine did not publicly share or discuss her practice. Based on her lack of participation, it was difficult to determine her early status regarding classroom implementation. Her first journal entry provided minimal insight into her preliminary understandings of enactment. In it, Katherine described facilitation in very general or generic ways as she discussed the role of the teacher during discussions. Later in the professional development, a transformation occurred. Katherine not only shifted to publicly discussing her practice; she shifted to discussing her practice in precise, reflective, and candid ways. She shifted to discussing specific ways she facilitated discussions and elicited student reasoning. Her participation became more specific as well as more personal. The following episodes will illustrate that Katherine was able to reflectively discuss her enactment and identify her successes and challenges in implementing the practice of LMD.

Katherine advanced in both the preparation and facilitation of mathematics discussions. She celebrated her improvements related to introducing or launching a lesson, purposefully selecting student responses, and focusing on her learning target or goal for the discussion. Reflecting on her enactment, she described several tools she had gained as a result of the MPD. She stated that she was better able to "know what I needed to be looking for to bring in to the discussion" and "be more focused on that learning target that I want them to achieve for that day and how they would be able to do that." Additionally, Katherine described how she questioned students to better understand their reasoning and prepare for the mathematics discussion. She explained:

> While they're working I usually, I will ask a question, what are you doing here? Why are you doing this? How did you decide that this was what you wanted to do? When I look at the picture, what does this represent? What does this represent? And what are you doing? Are you putting the numbers together? Are you taking the numbers apart? Usually I get around to most of them. I try to hit the ones that I don't think that they might know what they're doing. I try to go to them and see what they're, see where they are.

Rather than use questions that lead students to a correct answer, Katherine utilized questions to uncover student thinking and understandings. Her specific and purposeful questions helped her prepare for leading the discussion and respond to her students' mathematical needs. By carefully analyzing her students' work and questioning to reveal their understanding, Katherine was better able to identify her students' strengths and weaknesses and address them during discussions.

Katherine not only improved the ways she prepared for LMD, she also improved the ways she facilitated mathematical discussions. She became more focused during

discussions, able to attend to her students' needs while advancing the mathematics goal of the lesson. In debriefing one of her mathematics lessons with a PD instructor, she readily identified the goal of "counting on" based on the needs of her class. This was a clear focus of the lesson because her students were not utilizing this strategy and progressing to efficiency when solving problems. She stated,

> And that's what we've started working on this week is the counting on. And that's, we hadn't worked on when we did that, we started because I noticed in that lesson that most of them do not count on…So that's what we're going to start working on because that is where they're weak. They're weak in the counting on area.

She was in tune and responsive to both her students and the discipline. She was able to adjust her instruction based on what she had observed. Additionally, she understood how to utilize mathematics discussions to advance her goal and move her students along the continuum of efficiency.

Katherine openly identified her strengths and improvements in LMD. She also recognized her challenges and pinpointed areas of growth in orchestrating a discussion. In this instance, she discussed her reliance on one student as a catalyst for beginning the discussion and how she planned to change this action. She reflected:

> I don't think I really noticed this as much until after he was gone. And it's like the other kids would talk a lot after he got started, after this one child would get started. But he really was the catalyst. He was the one that would kind of get an idea going and get their thoughts going and I think I'm going to have to, I'm going to have to focus more on helping some other kids get a little bit stronger and what kind of questions they would ask.

Instead of placing blame or making excuses for a lack of participation, Katherine carefully analyzed her classroom interactions. She took ownership as a teacher and understood her role as a facilitator. She vowed to increase her students' confidence and use questions to encourage them to talk and participate.

Katherine acknowledged that discussions were the "hardest part" for her. She found it difficult to shift to a student-centered approach. She stated, "I mean that's just a whole flip for me and it's something that I definitely see the value of and I think that they're headed that way but we're just going to keep working toward it." Her later participation revealed her perseverance, positive attitude, and reflective character. She was willing to "keep working toward it" because she valued the practice for both herself and her students. Although challenging, LMD developed as an asset and strong point for Katherine, as evidenced by her enactment. Over the course of the professional development, Katherine shifted to a more integrated and explicit understanding of how instructional practices relate to support student learning. She demonstrated an understanding of high-quality mathematics practices and focused on the personal actions that she took in her classroom to enact the practice of LMD. She realized that teachers take an active role in orchestrating productive mathematical discussions.

Identity. Katherine entered the MPD as what some might characterize as a shy and introverted participant, reluctant to discuss her classroom practice or openly share her experiences. By not participating, she displayed a lack of competence and confidence in the practice of LMD. During PLTs, she relied on others for help and support and attributed her success to members of the community rather than herself. She did not

identify as a competent mathematics student or a reform mathematics teacher. However, as the MPD progressed, Katherine became more confident in her knowledge and understanding of LMD. She shifted from being a reserved, quiet participant to one that publicly shared her practice with her colleagues and the professional development community. The following examples will demonstrate a shift in both identity and confidence for Katherine.

During one interview, Katherine revealed how she openly and publicly discussed the practice with her grade level team, school staff, and the Core Math community. She described instances where she planned mathematics lessons with her grade level, presented during staff meetings at school, and opened her classroom to allow other teachers to observe mathematics lessons where she implemented the new instructional strategies. Katherine expressed her improved confidence and leadership during grade level planning, by saying:

> Well definitely with kindergarten math with the kindergarten team with math planning and math. I feel like that both Bethany and I can bring a different perspective to the planning. That we're able to add some things that wouldn't be there if we had not had the Core Math II.

She continued, describing her leadership at the school level:

> I feel like at McDonald that everybody has been encouraged and they have been given the opportunity to go into our classrooms and see what we're doing and we've spoken at staff meetings so that they do have some idea about Core Math so I think that's been real helpful and I think that's made it easier for us and I think it's something that our students need to be able to if you start at kindergarten I think they need to be able to go to first grade and get that same kind of instruction and keep moving forward with that.

She went on to say:

> They (administrators) have been very supportive as far as letting teachers that haven't had the opportunity to be in Core Math go into our classrooms and watch what we're doing and encouraging them to take some of those strategies back with them.

It is apparent that Katherine gained new levels of confidence in LMD. She became a leader both within her grade level and her school. She contributed to grade level planning meetings with new enthusiasm. She willingly shared her learning and participated as a competent member of the group. She felt that she added to the planning sessions, asserting that she brought a "different perspective" because of her Core Math experience. Katherine also participated in new ways within her school community. She encouraged fellow teachers to adopt and implement the practice of LMD by sharing at school-level faculty meetings and opening her classroom for visits and observations. Her hope was that teachers would "take some of those strategies back with them" and students at all levels would benefit from the "same kind of instruction" involving rigorous mathematics discussions. This was a dynamic shift for Katherine, and she exuded confidence and competence as a reform mathematics teacher. She expanded her identity as well as her value for the core practice beyond her classroom to the school.

The previous collection of episodes demonstrated that Katherine began to position herself differently throughout the professional development. Katherine shifted from assigning competence to others to drawing upon her own competence to participate. She shifted from being a quiet, reserved participant to a leader in her grade level team and at

her school. As a result, Katherine gained new levels of confidence, dramatically influencing both her identity and her participation.

Community. Early in the professional development, Katherine valued the community for support and collaboration. She respected her colleagues and appreciated their assistance as she completed PLTs. This was no different during the later stages of the MPD. On the final survey evaluating the MPD, Katherine wrote that "working with other teachers" was the most effective element of the professional development and added that a benefit of participating in Core Math was "the opportunity to work with other teachers."

The community continued to offer Katherine support and encouragement throughout the MPD, but in new and different ways. Members of the community shifted from helping Katherine solve mathematical problems to assisting her with issues of implementation and enactment within the classroom. She stated,

> We've built kind of a community amongst ourselves that we're able to, you know, discuss what we've learned and what we've used in our classrooms and how it's helped our students and what's worked and what hasn't worked. Umm, I think that it's made me more knowledgeable about how to teach math and how to help my students especially the struggling students, the one that don't always see it from that first perspective that you throw out there. I really feel like it's definitely been an asset and has broadened my horizons as far as being able to have more tools in my kit to help my children.

Describing the community as "an asset," Katherine demonstrated a tremendous amount of appreciation for the community. She contributed her learning and enriched mathematics knowledge to interactions within the community, stating that discussions within the MPD provided her with new tools, perspectives, and instructional strategies.

Katherine's value for the community expanded. Initially relying on the community for support as a student, Katherine shifted to relying on the community for support as a teacher. The community provided her with the support and encouragement she needed to enact a new model of instruction and significantly transform her identity.

Summary of Participation

Katherine's observable participation shifted as she grew in the community. Katherine moved from being a modest, reserved participant to one that confidently enacted a more integrated and specific understanding of LMD. As her confidence grew, she made her own practice public, resulting in learning for herself as well as others. Katherine's overall participation can be marked by quiet learning which led to confident and successful enactment and ultimately resulted in full participation within the MPD community.

The Case of Quinn

Quinn was a fourth grade teacher from McDonald Elementary School with 3 years of teaching experience. Quinn joined the MPD community with the intent of becoming a full participant. She entered as an active and enthusiastic participant who often contributed eagerly to group discussions. However, as Quinn struggled to renegotiate her identity, she failed to attain full membership. She failed to resolve tensions between her existing model of instruction and the new one presented in the professional development. Episodes from the MPD will describe Quinn's initial recognition of the practices involved in LMD and highlight the difference in her own meaning of mathematics teaching. As the MPD progressed, Quinn attempted to reconcile

the tensions between the models of instruction resulting in some shifts in the meanings and implementation of LMD. Yet, her progress, while significant, was not enough to resolve her tensions or become a full participant.

Despite tensions and apprehension, Quinn was receptive to learning and enacting the structure of LMD because the professional development community and her school community valued the practices involved in LMD. This structure allowed Quinn to make progress in enacting some of the less interactive practices associated with LMD such as creating tasks and focusing on learning targets. Quinn's success in enactment led to affirmation from both the professional development and school communities. This affirmation resulted in increased confidence in her ability to execute a new model of instruction. However, that confidence curtailed the work of resolving the tensions between the two approaches. Thus, the meaning she made only partially aligned with the community's meaning, and she failed to realize full participation. The following analysis will provide examples of Quinn's participation and describe her trajectory of participation. It will depict her evolution of understanding, practice, identity, and community involvement.

Initial Participation

Throughout the professional development, Quinn was an active participant. She often volunteered to share and was comfortable both expressing her opinions and asking questions. She eagerly contributed to small and large group discussions, collaborated with others to solve mathematical tasks, reported successes and challenges in enacting the practice of LMD in her classroom, and openly asked questions to her peers as well as the

MPD leaders. Quinn summed up her participation in the MPD in the following reflection by stating:

> I feel like I participated the most I could. I used examples from my classroom and defended my view points. I tried to allow others to talk and not feel left out. I offered to have videos shown to others and allowed people to observe my classroom and critique my teaching. I feel that my participation was useful to the conversation and added to the discussion.

Quinn participated in the MPD as a student and a learner. She was eager and fervent participant and often contributed to discussions. Collectively, the following examples will depict Quinn's participation in the MPD community and illustrate her initial interpretations of the meaning and purpose of the practice, the enactment of the practice in her classroom, her competence with the practice early in the MPD, and the MPD community support for her learning.

Meaning. From the onset of the professional development, it was apparent that Quinn valued the practice of leading mathematics discussions, at least to some extent. Her statements indicated that she recognized the importance of conducting classroom discussions in mathematics and valued students' ability to verbalize their thinking and construct viable arguments. This was evidenced during several occasions of the Summer Institute. On Day 2, the group read and discussed the article "Orchestrating Discussions" by Smith, Hughes, Engle, and Stein (2009). During the discussion, Quinn related the reading to the Mathematical Practices outlined by Common Core State Standards for Mathematics (CCSSM, 2010). She referred to the third Mathematical Practice: Construct viable arguments and critique the reasoning of others. She stated,

> A practice is to construct a viable argument over something that you have. Well if they can construct a viable argument, you know, then their job is to argue it and to try and understand others' arguments as well. Not just argue and be disrespectful, you know, do what I did and say, they have to listen but they also have to argue their point. You know and that's gonna help them better understand everyone else's choices as well.

On Day 3, participants watched a video of a third grade class solving and discussing a challenging mathematics problem. The video focused on the whole group discussion in which the teacher facilitated the sharing of three different solution strategies. After viewing the video, Quinn concluded, "Letting different kids verbalize it, you know, allows different levels of learning to come into play and you get more to kids understand if explain it numerous ways, not you but others." Both incidences demonstrated that Quinn valued opportunities for students to discuss mathematical concepts, verbalize their thinking, and argue various solution strategies. She attributed improved mathematics learning and understanding to such discussions.

However, Quinn's initial statements were broad and general, reflecting a surface level understanding of the practice of LMD. While she was able to recognize and discuss the practice, she often attended to shallow, superficial, and cosmetic aspects of the discussions. She focused on the form and function rather than the deep mathematics involved. For example, in analyzing videos of students' mathematics discussions she regularly highlighted the instructional moves and procedures used by the teacher. She offered recommendations such as, "She could have added a chart there. I feel like she could have created a chart." or statements of praise such as, "I liked that idea, after a kid's explaining, okay, who can tell me what just happened or who can explain that to me

again." At other times, she was intrigued by instructional strategies suggested by members of the MPD community. In one such instance that occurred after reading the article "Orchestrating Discussions" by Smith et al. (2009), the group discussed ways they prepare for LMD by monitoring students as they explore and progress through challenging problems. Several participants offered ways to keep students engaged with the task. Quinn chimed in by saying:

> As well as those early finishers giving them the anticipated strategies that you came up with on a separate sheet of paper and say okay, these are the strategies my kids came up with last year, whether they did or not. These are what they came up with last year, prove them wrong or prove them right. You know and that gives them something to do while you're helping those ones who are still struggling with it to you know.

As the group continued to discuss the reading, the topic shifted to the importance of being purposeful when selecting students to share their solutions during classroom discussions. Quinn offered an idea she discovered on a popular website. Quinn explained,

> Well, I saw something on Pinterest the other day. You took a solo cup and you put the toilet paper tube in it and the kids that you wanted to share you put in the toilet paper tube and everybody else you put on the outside and you drew the kids out of the toilet paper tube because those were the kids you wanted to share but it seemed random.

On a different occasion, Quinn described aspects of her mathematics classroom and the ways she had implemented LMD. Her statements reflected concerns associated with aesthetics and other non-mathematical issues such as clarity, neatness, classroom management, and organization. In her journal response, she wrote,

> I have found that it is really hard to choose students to share their ideas because they all have very similar answers or they got to the answer in the same way. I try to choose the ones who have spent their time wisely and their paper is nice and neat. My kids are also keeping math journals now. They keep all their work from the tasks in there so that I can look at them in one place and so that they stay organized.

Considerations based on organization and neatness took priority over those related to deep mathematical understanding. Central to Quinn's meaning of the practice were surface-level features related to actions and appearances.

Even her questions reflected a focus on the mechanics of LMD. For example, she asked members of the MPD community as well as the PD instructors how they would handle wrong answers, how to encourage students to discuss and share their solution strategies, or how to select and sequence student work. Her questions included: "How would you handle that?" or "So how would you coax them to tell you how they solved it or why they solved it the way they did?" The nature of her questions was related to the mechanics and actions of LMD. She was more concerned with the actions of implementation rather than understanding the reasoning for how and why to implement this core practice. Without shifting to asking more thought-provoking questions, Quinn was left to flounder with the motions of LMD.

This was due largely to the tensions she perceived between the two instructional models of teaching mathematics—the one she was most comfortable with and the one upheld in the MPD. Her existing model of mathematics instruction was vastly different. It was primarily based on traditional, teacher-directed methods. She struggled with integrating the new model with her current teaching. For example, during a discussion of

the article "Orchestrating Discussions" by Smith et al. (2009), Quinn was apprehensive of the time and effort required to prepare for LMD. She shared her concern by saying, "I feel like you're going to spend hours anticipating. And for me if I spend hours anticipating and my kids come up with nothing that I've anticipated then I'm gonna have spent hours for nothing." She goes on to say:

> Definitely not with every lesson . . . that's when I have a task. We're not having a task every single day, because I teach stuff . . . but when I do have one, to know that it's coming and be able to anticipate it. That would be good.

Quinn's comment, "because I teach stuff" implied that mathematical discussions centered around challenging problems are not teaching. It is evident that she struggled with her role in facilitating mathematics discussions and how these discussions resulted in student learning.

While Quinn's early understandings of LMD indicated broad understandings related to mathematics discourse, it seemed that Quinn struggled with integrating her current instructional practices based on direct instruction with the ones presented in the professional development. Her beginning statements focused on the importance of aesthetics such as organization and neatness rather than deep and purposeful mathematics learning. She was concerned with the mechanics and procedures of LMD rather than the purposes and intent of such discussions.

Practice. Despite Quinn's preliminary reservations and apprehension, she willingly attempted to enact the practice of LMD in her classroom. Early in the school year, after the first phase of the professional development, Quinn acknowledged that she

had “tried to implement a student-centered classroom.” Quinn reported some initial success, describing the progress she and her students had made. In her journal response, she wrote,

> My students are doing really well on the tasks that they are given. They are having good discussions and are coming up with really great answers and ideas on how to come to an answer. They have done a very good job of finding different ways to get the answer to a problem. They are coming to realize that one way is not the only way to answer a question. I have also gotten to where I look for mistakes in their work and have them explain to me how they know it's wrong and what they did to fix it. I find math much more enjoyable.

Quinn reflected on the successes she had experienced as a teacher as well as the improvements her students had made during the initial enactment of the practice of LMD. She attributed her students’ improved abilities to solve mathematics problems to discussions and even admitted to finding math more enjoyable.

Additionally, Quinn was open and honest about the challenges she encountered as she attempted to enact the new instructional strategies in her mathematics classroom. During the process, she sincerely shared her efforts, readily accepted feedback, and sought assistance from others by asking questions. She was candid and frank about her early struggles of enactment and worried about her abilities to realize the goals and intentions of high-quality mathematics instruction. She grappled with finding high demand, good quality mathematics problems, selecting students to share, and encouraging her students to verbalize and explain their solution strategies. Reflecting in her journal, she wrote, “My students sometimes don't want to talk or they have a lot of trouble verbalizing their solutions or ideas. They are fine when working with a partner

but they struggle with talking and explaining in front of a group." She continued, "I have found that it is really hard to choose students to share their ideas because they all have very similar answers or they got to the answer in the same way." By sharing both her successes and challenges while trying to implement mathematics discussions, Quinn demonstrated a mindset of reflection and improvement. Although apprehensive about the new practice, she was receptive and willing to undertake the challenge of reconciling her tensions between the two instructional models of instruction.

Identity. While Quinn was an active and willing participant, she displayed a lack of confidence in both her mathematical and teaching abilities. She often questioned herself as she solved PLTs. She quickly abandoned her answers or doubted the validity of her solution strategies, and she dismissed strategies that she did not understand by saying, "That's confusing to me" and "That seems too abstract to me." For example, Quinn displayed uncertainty as she solved the Horse Problem within her small group of five teachers. When questioned about the right answer, she immediately attributed the correct response to another participant. She asserted, "Oh, I'm sure she's right. I'm not a mathematically minded person." She quickly dismissed her answer as incorrect and demeaned herself as a mathematician.

During another episode, the large group discussed the selection and sequence of a set of student work samples. One solution strategy involving negative numbers caused debate among the participants. Quinn regarded the strategy as confusing and difficult to understand and admitted, "To think about negatives really boggles my mind. I wasn't so good with negatives anyway." As a result, she was unwilling to share the strategy with

her students. She maintained, "I don't want to go into that whole other ballgame of negatives. That to me is going to cause more trouble than it does good."

Quinn not only lacked confidence in her abilities as a mathematics student and learner, she also lacked confidence in her abilities to teach mathematics and enact a new model of instruction. The following episodes exposed such insecurities. After reading "Orchestrating Discussions" by Smith et al. (2009), Quinn summed up the five practices for orchestrating classroom discussions—anticipating, monitoring, selecting, sequencing, and connecting—as described in the article. Following her description of the process for preparing mathematics discussions, Quinn declared, "I was really intrigued by how it all seemed to flow. I'm not so intrigued on my ability to make it flow. That's where I, like I love that it works for these people. That's great." She went on to say, "It was one of those things where it sounds really well, but I don't know that I could do it yet." It was apparent that she was not confident in her abilities to implement the practice in her classroom. Before she even attempted enactment, she already questioned whether she could do it and "make it flow." By referring to "these people," she made it clear that she did not identify with the new model of instruction. Such a vision seemed foreign and unachievable. Quinn attributed this lack of confidence to her inexperience and deficient knowledge of high-quality mathematics instruction. She stated,

> I think it was a new concept for me. I don't remember learning it in school. I was learning from step one because I don't remember. I was on a reading focused team here at UNCG so I didn't, we didn't focus a lot on math. I had one math class. And so that one math class that I remember I don't remember much student centered instruction so I was learning really from day one because I didn't have any background knowledge.

While Quinn was able to recognize and discuss the practice of LMD, she was not confident in her abilities to realize and achieve the vision of mathematics instruction fostered in the MPD. She had difficulty identifying as a competent mathematics student as well as a reform mathematics teacher.

Community. Early in the professional development, Quinn valued learning in the MPD community. She worked with others to solve mathematics problems, compare solution strategies, and analyze student work samples. On several occasions, Quinn interacted with other participants to solve challenging mathematics problems. She described one such interaction with colleagues as they solved the Horse Problem:

> I was over here with Beth and Victoria yesterday. What we did is we did a whole lot of proving each other wrong but trying to see why it was right which is kind of what they did. They wanted to know why each of them got the answer that they got. And then after that we talked about how would you, how do you plan for a task like this.

Quinn credited the first phases of the professional development for allowing her to experience "what it was like to have to struggle through a problem." During PLTs, she tried to understand various strategies and make sense of methods different from her own. She reflected on the differing approaches by saying, "I was just trying to visualize it in my head but that makes sense now," "It's more of an organized version of guess and check," "So it's kind of interesting to see the two different, separate grade levels on the opposite ends of our grade levels," and "This was visual and I could hold things." Her statements indicated an appreciation for her colleagues and their alternative solution

strategies. Interactions with the MPD community allowed her opportunities to learn from others, discuss mathematics instruction, and share ideas for classroom implementation.

Moreover, Quinn felt comfortable in the community sharing areas of confusion and asking questions related to specific instructional moves. For example, during one discussion focusing on how to contend with wrong answers, several participants offered suggestions and described classroom activities that could be utilized to encourage students to analyze and discuss varying answers. Quinn interjected with the following question:

> Question. How would you handle that? I really would like to, I would as a person who doesn't do a lot of these type of things, I've done a couple but we've either run out of time because they've taken too long to do the problem or I don't know which ones to put up first.

Quinn sought assistance from the community by asking a question related to specific instructional strategies. She valued their opinions as well as their suggestions related to instruction.

Quinn realized the value of learning in a community and appreciated the merit of collaboration and problem solving. She collaborated with small groups to solve mathematics problems, questioned the methods of others, and compared and analyzed various solution methods. She respected her peers and sought their advice and support in both learning and implementing a new model of instruction.

Later Participation

In the early phases of the professional development, Quinn eagerly participated as a student and learner, solving mathematical tasks and collaborating with others. She

valued learning new strategies and productively struggling to solve mathematics problems within the MPD. She willingly attempted to enact the practice of LMD in her classroom and discussed her successes and challenges within the MPD. However, Quinn lacked confidence in both her mathematical and teaching abilities. She had difficulty identifying as competent mathematics student as well as a reform mathematics teacher. This was largely due to the tensions she perceived between teacher-directed and student-centered mathematics instruction. She focused on the form and mechanics of implementation and struggled with shifting her current instructional practices.

Quinn continued to participate as an active, eager, and reflective learner in the later stages of the MPD. She expanded both her value and understanding of mathematics discussions, overcame several challenges with enactment, and gained a boost of confidence when affirmed by the school and MPD community. Unfortunately, Quinn failed to reach full participation in the MPD community. While she made some progress in her understanding and enactment of the practice of LMD, she was fixed on the structure and mechanics of LMD. Improvements in her enactment were quickly recognized by the community and Quinn was thrust into leadership roles. When competence was assigned early by her school community, a disparate meaning became established and Quinn neglected to shift. The following episodes will demonstrate that Quinn failed to resolve tensions between the differing views of teaching, resulting in peripheral participation in the MPD.

Meaning. By the end of the professional development, Quinn had a clearer understanding of the purpose and intent of mathematics discussions. She valued the

practice and considered it to be best for her students. However, she continued to struggle with understanding her role as a teacher in leading these discussions. She wrestled with integrating different instructional moves and models of teaching, understanding how each contributed to student learning. She was also concerned with challenges such as parents and the pressure of district and state assessments.

Later in the professional development, Quinn's statements demonstrated that she valued the practice of LMD for her students. She considered the practice to be best for students, promoting perseverance and determination. In one interview, Quinn expressed such value by saying:

> I think it attributes to the, that we see it working and that we see it's a best practice and that's what our school wants for our kids is for them to get the best that they can and them talking through it and them working through it. That's the one thing we focus on really big at McDonald is what's best for our kids.

Quinn also valued the practice as a teacher. She recognized that mathematics discussions allowed her to more readily learn about her students' needs and misconceptions. She explained,

> I've learned so much just watching my kids as compared to me standing up there and teaching all day and giving them homework and they come back and half of them have failed it because they don't know what they're doing. Whereas giving them that here's your launch now I'm going to walk around and watch you explore, I catch their misconceptions before they spend all class period doing it. Whereas, in my past classes, I didn't catch it until test day.

Quinn strengthened and extended her value for mathematics discussions over the course of the MPD. Based on her experiences, she concluded the practice to be best for her

students. Moreover, she discovered the practice to be beneficial for her as a teacher. She was better able to attend to her students' current mathematical understandings and misunderstandings as well as monitor and address misconceptions in a timely manner.

Quinn also gained a deeper understanding of the purpose and meaning of LMD. However, this meaning was closely tied to the organizational structure presented in the MPD. Mathematics lessons were organized into three components - launch, explore, and discuss. During these lessons, an engaging problem was launched and presented to students. Students then proceeded to explore the problem as individuals, partners, or small groups. A whole group discussion followed in which selected students shared, compared, and connected their solution strategies for the problem. Quinn connected with the structure for LMD. She was not only able to recognize it, but she was able to implement it successfully in her classroom.

Quinn's understandings of LMD focused on form and organization. The MPD provided a structure or formula for teaching mathematics in student-centered ways. She adhered closely to this structure and found it comforting as she enacted a new model of instruction. In the following episode, Quinn attributed the structure to an improvement in trust and engagement. She shared during one professional development session:

> I would have never given my kids this much power. Not that they have power . . . but as much trust as I do. For them to know that if I go over there that's what they're going to be working on. They're not going to be playing. Whereas, in the past classes, I would never have done that. But it's that structure, they're used to seeing it on the very first day and they knew it was going to be part of their day every day.

According to Quinn, this structure made LMD manageable for both the teacher and the students. As evidenced by her statement, "We know that the launch, explore, discuss type scenario is what's best for our kids."

Quinn appreciated both the structure and value for LMD she acquired through the MPD. However, the meaning Quinn developed only partially aligned with the meaning of the community. The following episodes will demonstrate that Quinn continued to struggle with her role in LMD and how to balance different instructional models. During one interview, Quinn admitted that she misunderstood the purpose of the explore stage in a mathematics lesson. She did not consider it to be teaching and often jumped in to correct students' errors as they were solving the problem. Quinn disclosed,

> When I first started doing student centered instruction when we were taught it, I didn't really think about the explore phase as a teaching phase too. It was more of a watching phase but as we kind of got into Core Math II a little more she (Marie, MPD Facilitator) talked about questioning and why that was important to grow. Because I was the one that I saw them doing something wrong so I fixed it because it was just the, you know. But I've learned throughout this process that with implementing it with them watching and things like that, that it's important that I don't tell them, that they start to figure it out on their own.

It is evident that she grappled with her role as a facilitator. She concluded by saying, "It's important that I don't tell them, that they start to figure it out on their own." While this demonstrated some growth in understanding the core practice, she was still confused about her involvement and purpose during this stage of LMD. She neglected the importance of monitoring, selecting, sequencing, and connecting students' strategies as they work.

Quinn's struggle to understand her role in LMD was further evidence of the persisting tensions between teacher-directed and student-centered instructional models. Quinn continued to battle her beliefs and past experiences ruled by traditional, teacher-directed approaches. These tensions led to contradictions in her statements of meaning and understanding. She was constantly trying to make sense of the two opposing models, and her statements in one interview revealed this conflict. Quinn stated,

> At first I thought you had to do it every day, it was like a continuous student centered, student centered, student centered, and I struggled with that because I was like where is my teaching coming in except in that discuss part. And so that was the main, probably the main barrier is I kept doing these student centered learning activities but I felt like there were some days that I needed to teach and I felt like I was breaking the rules if I didn't teach or if I did teach and I didn't do a student centered learning activity. But that's not how when I was taught, the teacher did everything, I didn't. And so it was kind of nice to see that we were able to still do that but that shouldn't be the only way the kids learn, they need to learn from each other and things like that.

Although she acknowledged that students learn in different ways including from each other, she had difficulty integrating opportunities for discussion and collaboration into her daily instruction. Quinn did not regard student-centered lessons as teaching, because it was not aligned with her views and beliefs. Her tensions between the two instructional models remained unresolved, as evidenced by her inconsistent and conflicting statements.

Internal as well as external stress affected Quinn's understanding of the core practice. Adding to her tension of instructional models were pressures to perform on state and district assessments as well as pressure from parents. Quinn had difficulty negotiating such pressure as she tried to implement new instructional strategies. In an interview, she described her challenges with parents by saying:

> Parents have probably been my biggest one. I have a lot of parents who question why we do the tasks that we do and I tell them that we use the latest research. The latest research says that you know, students need to play with math and examine math and get math on their own and a lot of parents they were taught math. They were taught how to do multiplication the traditional way, this is how they learned it, they memorized it, they do it that way every day. I want my kids to understand what multiplication is not just how to do it and I've had to explain that to a lot of parents. I don't want your kid just to be able to multiply. I want them to know that multiplying means I'm finding numerous ways of doing or whatever. So parents have probably been my biggest struggle.

She continued to describe her challenges in LMD, focusing on district and state assessments. She went on to say:

> I just feel like sometimes we're, we focus a lot in Core Math on turning and talking and working with partners and that kind of stuff and I feel like our kids aren't quite prepared when they're given that abcd test and so I think that shows in our district test. Taking student-centered learning and taking it and applying it to a test is really difficult, at least for me. And that's probably where the district has constrained us the most because it's that we've gotta make this test. By the end of the year, they've all gotta know this by themselves abcd whereas that's not how you learn. You learn from other people and you learn from doing things and trying things and there's not always one way to do things or whatever. So I think that's probably where our constrictions are coming from, from a district and a state level but you can't fix that, you've gotta have a way to test them in some way.

Quinn identified both parents and testing as challenges to her implementation of the practice of LMD. These external pressures impeded her classroom implementation and constrained her learning. Quinn found it difficult to deal with external as well as internal pressures as she made sense of a new practice. Therefore, she was never able to reconcile the two models of instruction and never fully align her meaning with that of the MPD.

Practice. Despite a misalignment in meaning, Quinn exhibited a tremendous amount of growth in enacting mathematics discussions throughout the MPD. She overcame several of the challenges she identified during the early stages of enactment including obtaining high quality mathematics problems, facilitating classroom discussions, and anticipating possible student responses and misconceptions. In the following excerpts, she described specific areas of growth and learning.

In both surveys and interviews, Quinn acknowledged the improvements she made in relation to learning targets, questioning, and adapting mathematics problems. She realized the importance of planning goals and learning targets for mathematics discussions. She also understood that the learning targets she established for her mathematics lessons needed to be specific, yet reflect the needs of her students. In an interview, she stated,

> One thing I found very beneficial was the learning target things that we did and learning that they need to be specific . . . it had to be way more specific and then so knowing that they could change. It's okay that you change it for what your students need.

Quinn continued to reflect on her improvements of enactment. She wrote,

> One important thing that I learned was how to implement the launch, explore, discuss lesson plan. I used this regularly in my classroom and it was helpful in making sure I anticipated and wrote down my questions. Another thing I learned was how to question to get to my learning target. Learning to strategically question was very difficult for me and it took me a while to learn but the constant viewing of lessons and receiving feedback really helped to further my understanding.

Quinn learned how to prepare for LMD. By establishing clear goals, designing targeted questions, and anticipating student responses in advance, she was better able to facilitate the mathematics discussions in her classroom. The discussions were well planned and, therefore, became more deliberate and focused. Quinn developed the ability to plan and ask more strategic questions, leading to the realization of the lesson's learning targets.

Another way that Quinn prepared for LMD was by creating and selecting mathematics problems. Initially, Quinn struggled to find engaging and challenging problems for her students to solve; one of the barriers she originally ascribed to her inability to implement the practice of LMD. However, by the conclusion of the MPD, Quinn overcame this challenge by learning how to create and adapt mathematics problems to be suitable for her grade level and her students. She reflected in one interview:

> The only other barrier is it took us a while, it took me a while anyways I don't know about anybody else, but it took me a while to figure out how to write a task, like how to make one and then once I figured it out it was really easy. But it was like having to, I would get to the standard and I was like oh gosh, I don't even know where to begin writing a task for this so I would google it and well there aren't tasks out there. NCDPI has some but sometimes there weren't any for that specific standard so I didn't know where to go so it was that whole standard was teacher directed because I didn't know how to do it. It was a nice barrier to break so then I could see okay, I don't have to rely on a pre-made when I can make my own which was nice.

She continued to describe her ability to adapt tasks by writing:

> Finally, I learned how to adapt tasks to fit my classroom. Whether it was taking a second grade task and making it fit fourth grade or it is was taking a task I found and making it work in my classroom for my kids I feel that this was probably the

> most important thing that I learned because I was able to find plenty of tasks and make them my own.

It is apparent that Quinn made progress in enacting several instructional moves associated with LMD. She was able to overcome a number of the challenges she first identified in the early stages of the MPD. Challenges involved in the preparation of mathematics discussions became areas of growth and strength for Quinn. However, Quinn's progress reflected improvements in the methods associated with the structure and mechanics of LMD. She attributed her success to the three-part lesson design presented in the MPD by saying, "One important thing that I learned was how to implement the launch, explore, discuss lesson plan." Quinn's interpretations of LMD were influenced and restricted by this structure. She also made progress in establishing learning targets, designing questions, anticipating student responses, and creating mathematics problems. While critical in preparing for lessons, these mechanics along with the lesson structure were parts of the lesson that she could control and manage.

Quinn learned to implement a new structure for her lessons. While this restructuring did provide more opportunities for her students to participate in mathematics discussions, Quinn struggled with the more interactive and responsive aspects of LMD. It was difficult for Quinn to extend discussions to deep levels, respond to unanticipated errors and misconceptions, and connect and expand on students' ideas and strategies. For example, during a debriefing session with one of the MPD instructors, Quinn reflected on one of her videotaped mathematics lessons. As they watched and discussed the lesson, she reflected on her progress and willingly admitted areas of

strength and growth. Quinn admitted, "That's probably my biggest struggle…The discuss is where I struggle. It's like how do you? I don't know. How do you know when to dig a little deeper?" She struggled with being responsive to students and extending their mathematics learning and understanding through discussions. Quinn was unable to move beyond the mechanics of LMD to a deeper meaning and enactment of the practice.

Community. Over the course of the professional development, Quinn made it clear that she valued learning mathematics in a community. This was evidenced in the early phases of the professional development by her interactions with her peers as she solved mathematical tasks and discussed instructional practices. In later phases, Quinn became more reliant on the community for support as she implemented the practice of LMD. She shifted from valuing the community for helping her as a mathematics learner to helping her as a mathematics teacher and instructional leader. The MPD community, consisting of teachers, administrators, and the PD leaders, became instrumental to Quinn's growth and learning. Affirmations from the community attributed to improvements in her confidence and implementation.

Quinn appreciated the community for providing the support she needs to enact the practice of LMD. She acknowledged the importance of having support from her colleagues, her administrators, and the professional development instructors in the Core Math community. The support she received allowed her to deal with challenges and external pressures as she implemented a new instructional model for teaching mathematics. In one interview, she stated:

> I enjoy being able to come and not just talk with people in my school but talk with people from another place who are dealing with the same things I am because we don't get that opportunity a lot even at a district level. We don't get the opportunity to talk from teachers, to teachers from other schools to see what they're struggling with so it's kind of nice to get to come and bounce ideas and explore together with another set of people. You know being able to have that collaboration is kind of nice.

In a second interview, Quinn affirmed the support she received from the MPD community. She acknowledged the importance of collaboration with her colleagues as well as the professional development facilitators (Marie and Deneen). She stated,

> As a member of the core math community I feel like I have benefited from the collaboration from Marie, Deneen, and my other colleagues. It was beneficial to come to Hillside and get to talk out challenges and strengths and to share ideas with a great group of teachers. I got lots of ideas about ways to better my instruction and ways to hold my students accountable. Deneen and Marie were also very good idea bouncers. I constantly used them as my email buddies because I needed to have an idea approved or added to. I also enjoyed them coming into my room and analyzing what I did and ways that I could better my instruction. The feedback portion of this was definitely helpful as well as people sharing videos in the meetings.

Quinn appreciated opportunities to interact with teachers from a different school as well as the MPD instructors. These opportunities allowed her to exchange ideas, share strengths and challenges, and receive feedback to improve her instruction.

Quinn also recognized and appreciated the support she received from her administrator. Whitney, Principal at McDonald Elementary, was a regular participant in the MPD. She offered support to her school's participants in the MPD and was instrumental in implementing the professional development to her entire school. She

offered feedback to her teachers and promoted collaboration among grade levels at her school. Quinn acknowledged and described this support during an interview. She stated:

> Student centered learning is proven to be one thing that's really good for our kids and so she's (Whitney) been very supportive in it and she's been very instrumental in making sure that everybody is on the same page whether they're in Core Math II or not. She has expected us to talk with other grade levels about it, she's expected us to go to other grade levels and plan with them and do, you know. And we've done vertical planning where we go in and third grade came to our PLCs and we were able to share with them what we want their kids that they have now to know by the time they get to us. And we were able to go to fifth grade and do the same thing. So she's very much into collaboration as a school, collaboration as a grade level. She's very much into that and she wants to be a part of it and she does walk-throughs and sit downs all of the time with us much like Marie does. And hers might be just a sticky note stuck to our desk of try this next time or I really liked this keep it up. Just those little things that keep us knowing that we're doing what we're doing. It's nice to have an administrator that's that supportive.

Quinn valued the support she received from the teachers, instructors, and administrators involved in the MPD. This support allowed her to improve her practice of LMD and gain confidence as a mathematics student, teacher, and leader resulting in shifts in her participation and identity.

Identity. While Quinn's willingness and eagerness to participate did not change throughout the professional development, her confidence and role in the community did. Early in the professional development, Quinn exhibited low confidence in her abilities to enact the practice of LMD in the classroom. Initially, she was unsure that she could orchestrate classroom discussions or anticipate student solutions before implementing mathematics problems. She doubted her competence both as a mathematics student and a mathematics teacher. At one point, she even claimed that she was "not a mathematically

minded person." However, by the end of the professional development, she was not only effectively enacting aspects of the practice in her own classroom; she was also guiding others at her school to do the same. As a result, Quinn exuded new levels of confidence and self-assurance. Over time, Quinn became more confident as a teacher and a leader in her school community.

As the MPD progressed, Quinn grabbed hold of the structure of LMD and successfully enacted this structure in her classroom. Her progress was endorsed and recognized by both the MPD community and her school community. As a result, Quinn's confidence grew and improved, eventually extending beyond the classroom and positioning her as a leader. Quinn reflected on her confidence by writing, "I felt very confident about what I had learned and was very open to sharing. It was easy to share because we had grappled with some of the same things other teachers deal with and help them get through it."

As the following examples illustrate, she became a leader in her school community and an advocate for high-quality mathematics instruction. She presented at grade level PLC meetings and school-wide staff meetings, allowed other teachers to observe mathematics lessons where she implemented the new instructional strategies, visited classrooms to provide teachers with feedback, and answered questions regarding the new instructional model. During one interview, Quinn described her role as a teacher leader and advocate for the new practice of LMD. She stated,

> I have a responsibility and it's a very big one. I have a responsibility to take what I believe will work and do my best to share. And it's worth it. And it's my responsibility because if I believe it, I'm going to be much more passionate about

> the way that I teach and people that come in and observe. We do a lot of, can I go observe her? And then we get to go. That happens a lot and I feel like that if they come into my room and that's what they see and they see it working and we give it the chance to work. Then I think we're going to see masterful mathematicians at our school.

Quinn believed she had a responsibility to share what she had learned in the MPD. Her classroom was established as a model classroom where other teachers in her school could observe her teaching mathematics. She gained both passion and confidence in opening her classroom and sharing her practice with others.

During one interview, Quinn explained how she along with other members of the MPD helped her school community learn about the practice of LMD. She shared aspects of the MPD at school faculty meetings and grade level PLC meetings and assisted individual teachers in implementing the new model of instruction. She explained:

> Other grade levels have learned from us. We've brought back, during PLCs and during staff meetings we've been asked to present or just talk about what's kind of been going on in Core Math and what we've been talking about. For example, the launch, explore, discuss task presentation. Whitney asked us to come back and share that with our staff and then our staff began using it. And then it was a lot easier to teach, you know because everybody is now teaching math the same. People come and talk to us about a math problem that they have and then Whitney also uses us she points them in the direction of us knowing that we can help them in some way, you know get better at teaching math or explain something to them that they might not have gotten from our whole group discussion. They know they can come to us if they have a question about how to teach it.

It was clear that the principal quickly positioned Quinn as a leader in the school community. Quinn was not only responsible for sharing the structure of LMD with her colleagues; she was also responsible for assisting individual teachers with questions or issues of implementation. Additionally, Quinn had opportunities to observe other

teachers at her school enacting mathematics discussions. She described one such observation by saying:

> When I peer observed, I actually peer observed a third-grade teacher who was not in Core Math I or in Core Math II and she was using that launch, explore, discuss and I was so happy seeing her do it that when I went to do her post-op I was like I'm so excited to see you doing it because she did everything that we did and she even asked me a question, how would you have done this differently or how would you, you know? And there wasn't a lot I could tell her because everything she had done, her questioning was great, it was things she had, things that I was glad to see. McDonald has done a really good job of making that, our school community, making sure that we collaborate together to do that.

Quinn valued these leadership experiences. She enjoyed opportunities to share with her fellow teachers and contribute to the enactment across her school. As a result, she gained confidence as well as a new appreciation for the practice. In her evaluation of the MPD, she wrote:

> The other most effective element was when I was able to go back to my school and share with my cooperating teachers what I learned and watch them use it in their classrooms. It made me realize that what we are doing is very important to the foundation of math.

As Quinn learned and was affirmed by the MPD and school community, she became more confident in her ability to enact the practice of LMD. Recognition and endorsements from both communities transformed her participation. Quinn initially identified as an incompetent mathematics student and teacher. Over time, Quinn gained new levels of confidence and self-assurance as she successfully enacted aspects of the practice and shared her learning with her colleagues. She was positioned as a competent teacher and leader, particularly by her principal. However, this quick thrust into a

leadership role stifled her growth and learning. Experiencing early success in enactment and shifts in her identity, Quinn became over-confident in her abilities. This was evidenced by changes in her participation. Quinn's initial questions reflected anxiety and questions of implementation—"How do I do this?" Her participation later changed to statements of confidence—"I've got it." As a result, she failed to continue to learn or make progress. Quinn remained focused on the structure and mechanics of LMD throughout the MPD and as she assisted others with implementation. This confidence curtailed the process of reconciling tensions between her existing model of instruction and the new model presented in the MPD. Thus, the meaning she made only partially aligned with the community's meaning.

Summary of Participation

Quinn was an active participant in the community who was receptive to learning a new model of mathematics instruction. As she learned and was affirmed by her community, she became more confident in her ability to enact high-quality mathematics instruction. However, Quinn remained focused on the structure and mechanics of LMD and continued to have unresolved tensions between her existing model of instruction and the new model. As a result, she never fully aligned her meaning with that of the community. Success in enactment and affirmation from community prevented further learning and progress. Therefore, Quinn failed to reach full participation in the MPD community.

Similarities and Differences

The previous section described four teachers' trajectories of participation as they engaged in MPD over the course of a year. Each case was distinct and unique, offering insight into the teachers' learning of the core practice of LMD. By presenting changes in their discourse, the analysis revealed each teacher's learning of the practice characterized by meaning, practice, identity, and community support. In the next section, I will compare the teachers' trajectories of participation and highlight the similarities and differences across cases.

Similarities

Although each trajectory of participation was different, three of the four cases led to full participation and membership in the MPD community. Danielle's participation, marked by eagerness and reflection, was consistent, focused, and led directly to full participation. Carol's indirect trajectory was one of ongoing growth and persistence that eventually led to full participation. Lastly, Katherine's participation transformed from marginal participation to full participation. By the end of the MPD, these teachers' discourse reflected a meaning of the core practice that aligned with the community, and the community recognized each of them as competent, contributing members.

While there were many similarities and differences among them, there was one notable similarity. Foremost, Danielle, Carol, and Katherine attended to students in similar ways as the MPD progressed. Though initially centered on personal struggles with implementation of the core practice, their discourse shifted to primarily focus on the learning and progress of their students. In the following section, I describe the

transformation in participation from self to students which over time led to their full participation and membership in the MPD community.

Attention to students. Though multiple factors lead teachers to change their teaching practices (Clarke & Hollingsworth, 2002; Guskey, 2002; Richardson & Placier, 2001), Danielle, Carol, and Katherine's focus on student learning was a common theme that motivated their participation in the MPD. When the three teachers first came together during the summer institute, their discourse reflected concerns about their own learning and abilities to lead mathematics discussions. Episodes of participation were marked by insecurities, broad and general understandings, tensions amongst instructional models, and challenges with enactment. However, as the MPD progressed, the teachers focused less on themselves and moved to focusing more on their students. I propose three reasons for this shift of attention. First, the teachers experienced and valued mathematics discussions first hand and wanted to create similar experiences for their students to engage with mathematics. Next, the teachers saw evidence of their students succeeding and learning as a result of implementation. Finally, the teachers found that they were better able to differentiate and meet the individual needs of their students by LMD. I will describe each of the factors in the following section.

Extending value. All three participants had opportunities to experience PLTs in the MPD setting. They persevered in solving challenging mathematical problems, interacted with colleagues to discuss and compare possible solution strategies, analyzed and critiqued the reasoning of others, and connected mathematical concepts in order to establish relationships. By participating in mathematics just as students would, the

teachers gained a greater appreciation and understanding of mathematics as well as the importance of discussions. They valued opportunities to discuss and collaborate with their peers and engage actively in mathematics discussions and problem solving. Carol summed up her feelings by saying, "This is so important to me."

Both Carol and Danielle participated actively within their groups to solve mathematics problems and discuss challenges of enactment. They appreciated different mathematical strategies, explored the reasoning of others, and reflected on their own mistakes and methods. Carol made her value clear by declaring, "That's why I like collaboration." Katherine, who rarely contributed to whole group discussions, recognized and appreciated the ways the group supported her learning when solving the Horse Problem. She stated that Erin's questions helped her "thinking a little bit more" and "made sense," allowing her to reach a solution she understood. All three indicated that the support and collaborative interactions with others in discussions contributed to their own learning.

These early experiences with mathematics discussions were the same types of opportunities they wanted to create for their students. They valued the core practice of LMD and began linking that value to their own teaching and students. To immolate her experiences, Danielle used some of the same problems from the MPD with her second grade students. She maintained that she could "take the real life examples and apply them to my class even if it was a problem that the adults did." Goals for lessons resembled their experiences and qualities they came to value. Danielle shared the goals for one of her video-taped lessons by stating:

> But my learning target for my kids was basically just making sense of the problem and exploring their math. We have worked tirelessly on word problems, making sense of it. So that was my main focus for them. Yea, exploring their math. So trying different strategies and finding one that they were comfortable with for this problem.

She later added, "Because that's what we're trying to work on is comparing strategies, seeing the similarities . . ."

Carol described similar goals for her lessons. She expressed value for cooperative group work, student understanding, and multiple solution strategies. In surveys and interviews, she reiterated the same sentiments by saying such things as, "I think they have to understand what they're trying to do," "I really need them to understand what to do and why," "We're here to, you know, work together to figure out what the problem is or how you guys can solve it . . ." and "Let the kids discover math or solutions on their own." Katherine also provided her kindergarten students with opportunities to explore, work together, and learn from one another—all activities that she had personally experienced in the MPD. In the fall, she reflected in her journal, "There is a lot of discussion among the students as they work together to find solutions to problems" and "Students explore ideas and learn to value ideas from their peers as well."

All three participants were committed to their students. Their contributions to discussions in the MPD and reflections in journals and interviews suggested that they valued participating in mathematics discussions as learners and wanted their students to have these same types of educational experiences. As the MPD progressed, they worked to create these same experiences for their students.

Student outcomes. The teachers not only experienced success and learning as a result of participating in the MPD, they quickly recognized that their students were positively impacted as well. After implementing mathematics discussions in their classrooms, all three began to see evidence of student learning and success. Katherine boasted of both mathematical and non-mathematical improvements her students had achieved as a result of incorporating discussions in her teaching. She maintained that her students gained language and social skills, confidence, and the ability to collaboratively work together. She also observed improvements in their number sense and mathematical understanding and affirmed that they were better able to explain and model such understandings. Similarly, Carol upheld that mathematics discussions contributed to students' learning, engagement, confidence, mathematical understanding, and overall success. Both in surveys and interviews, she reflected on the ways discussions helped her students. She enthusiastically declared, "The kids in my class have enjoyed the way I taught this year. They also seemed to grasp more of the lessons than previous years." For Danielle, mathematics discussions around a challenging problem led to improvements in her students' engagement, excitement, independence, agency, perseverance, and overall mathematical understanding.

Such success and improvements motivated the teachers to persist at learning the practice of LMD. Although adjusting their practice was novel, time consuming, and challenging, the teachers were committed to enacting the new model of instruction due to the positive impact it had on their students. Carol emphatically declared, "It's encouraged me, it's encouraged that through me you know the kids have succeeded so I

more than welcome a change." Katherine offered a similar sentiment by saying, "I mean that's just a whole flip for me, and it's something that I definitely see the value of, and I think that they're headed that way but we're just going to keep working toward it." She was willing to "keep working toward it" because she was able to "see the value" when her students demonstrated evidence of learning. Danielle also recognized the benefits mathematics discussions offered for her students' learning and appreciated the long-lasting results that developed as a result of implementation. She described her experience by saying, "A positive challenge, because it has challenged the way I teach, the way I think about teaching in a positive way."

Convinced that the practice contributed positively to their students' learning and achievement, the teachers enacted the practice of LMD even when it was difficult and radically different from their previous approach to teaching mathematics. Carol embraced and welcomed the change and saw it as an opportunity for professional growth. Katherine continued to persevere as she shifted to a student-centered approach, and Danielle proclaimed the experience "as a positive challenge," realizing that the benefits were well worth the extra effort and instructional time. Mathematics discussions were important to each of these teachers. Because they valued and prioritized student learning, they engaged in the MPD to improve their practice of leading them.

Differentiation. A third motivating factor related to students was differentiation. Each teacher recognized that mathematics discussions allowed them to more effectively differentiate their mathematics instruction and meet the individual needs of their students. Carol noted a new flexibility in her instruction and simply stated, "It has allowed me to

change the way I teach certain standards that are more appropriate to the kids' learning styles." Katherine credited her improved questioning skills for helping her identify her students' strengths and weaknesses and better respond to their mathematical needs. She became more responsive and attentive to her students upon enactment. Likewise, Danielle developed both a strategic and focused approach to her teaching. In discussing her facilitation of discussions, she learned "strategically to help my students grow mathematically." Both her awareness and attention to students improved. She stated, "I had to be very cognizant about how my kids were and make sure that they had varied numbers that they were working with . . ."

Accordingly, the teachers' goals and learning targets improved. Both Katherine and Danielle moved from designing lessons with broad and general goals to specific learning targets that were reflective of their students' needs. For Katherine, the purpose of leading discussions shifted from generic goals, such as students working with peers, to more specific, mathematical goals, such as learning about the addition of doubles, efficient strategies such as counting on, and how to measure and sort. By better understanding her students' needs and misconceptions, Katherine became more purposeful and selective. She was able to precisely select numbers for problems and accurately identify the mathematical goals she intended to advance in her discussions. A similar occurrence took place for Danielle. As her understanding of both the practice and her students' mathematical thinking evolved, her instructional moves became more focused and purposeful. She was able to discern specific learning targets for the lesson

and make purposeful decisions as she selected and sequenced students' solution strategies.

The three teachers were motivated by their students. Their interest in, and commitments to, their students were strong motivating factors in learning a new instructional practice. This motivation encouraged their participation in the MPD community and allowed them to persist through the tensions between their existing model of teaching and their commitments to learning to lead mathematics discussions with their students.

Differences

Over the course of the MPD, Danielle, Carol, and Katherine's participation shifted from personal learning to student learning. The teachers focused less on themselves and moved to focusing more on their students. Their statements reflected an appreciation and value for mathematics discussions, and they attributed their students' progress and success to implementation. The teachers became less concerned with personal successes and challenges of enactment and more concerned with meeting the individual needs of their students. However, unlike the previous three cases, Quinn's trajectory of participation never led to full participation and membership in the MPD community. In the analysis of her discourse, there was a striking difference as compared to the discourse of the other three. Rather than shifting her attention to her students, Quinn continued to focus on herself as a teacher and learner. Her statements largely reflected concerns with her own learning and progress as opposed to her students' learning. Quinn valued the core practice of LMD, not because it was beneficial to her

students, but rather because it was an expectation of her school. She was confused about how the practice contributed to student learning and became frustrated when it did not align with her understanding of the district and state assessments. With a strong focus on structure and mechanics of LMD, she was unable to make sense of and enact the practice in ways that met the individual needs of her students. In the next section, I describe three aspects of Quinn's participation—value, student outcomes, and differentiation—to demonstrate the persistent attention to herself over the course of MPD.

Extending value. At first glance, it appeared that Quinn valued the practice of LMD and considered it advantageous for her students. She described the practice as "a best practice" and "best for our kids." However, upon further analysis, Quinn's statements do not reflect her own sentiments but rather those of her school and her administrator. In one interview, she stated,

> But I think it attributes to the, that we see it working and that we see it's a best practice and that's what our school wants for our kids is for them to get the best that they can and them talking through it and them working through it allows them to get that talking done and then they've seen the growth. And Whitney has kind of expected it of us. She's said you know I want to see this kind of format because that's what's best for our kids and that's the one thing we focus on really big at McDonald is what's best for our kids.

By stating "that's what our school wants" and "Whitney has kind of expected it of us," Quinn recognized the practice as significant because it was valued by both her principal and her colleagues. Early in the school year, Quinn's lesson included a mathematics discussion. In her interview, her statements implied that her enactment was more motivated by an expectation of the school, the district, and the MPD than her belief that it

was best for her students. Later in the interview, she stated, "Well it's, it's very much a requirement, it's not a requirement, I shouldn't say requirement. But it's very expected I guess . . ." Multiple communities were pressuring her to change her practice and include more student discussions. Whether she believed in the practice was inconsequential, she was fulfilling the demands of her school administrator and complying with the expectations ascribed by the MPD.

Quinn's statements were not void of value. She did not disregard the practice or dismiss it as being useless. Instead, she valued the core practice for herself and what it afforded to her as a teacher. She understood the purpose and intent of mathematics discussions to inform teachers of student misconceptions, but did not see the practice as contributing to student learning and understanding. During the last days of the MPD, participants were asked to sum up their experience in one word. Quinn selected "beneficial" as her word and went on to explain the reasons for her selection. She stated, "I got lots of ideas about ways to better my instruction and ways to hold my students accountable." She further explained that the MPD helped her learn how to adapt and create challenging mathematics problems, develop specific learning targets, improve her questioning, and acquire a structure for orchestrating discussions. On the final survey, she wrote:

> One important thing that I learned was how to implement the launch, explore, discuss lesson plan. I used this regularly in my classroom and it was helpful in making sure I anticipated and wrote down my questions. Another thing I learned was how to question to get to my learning target. Learning to strategically question was very difficult for me and it took me a while to learn but the constant viewing of lessons and receiving feedback really helped to further my understanding. Finally, I learned how to adapt tasks to fit my classroom.

> Whether it was taking a second grade task and making it fit fourth grade or it is was taking a task I found and making it work in my classroom for my kids I feel that this was probably the most important thing that I learned because I was able to find plenty of tasks and make them my own.

Her statements reflect a value for the MPD. She credited the MPD for helping her learn and improve her enactment of the practice. However, value for the core practice was directed toward improving her teaching as opposed to the mathematical understandings of her students. In describing what she learned in the MPD, she focused on aspects associated with the structure and mechanics of the lessons. Each part of the lesson, the task, learning target, questions, and structure, was constructed by the teacher and could be controlled and managed. She struggled with implementing the more interactive, responsive, and unpredictable aspects of LMD that were influenced by students.

Therefore, Quinn valued and focused on the mechanics and structure of LMD. She adhered closely to the organizational structure shared in the MPD which provided a way to manage the unpredictability of mathematics discussions. She acknowledged this in one interview by saying:

> I am very . . . I need a first, second, third. I need you to tell me exactly what I need to do. And I think that's what it taught me was that there was a specific way of doing it and how to implement it and what steps you need to take to get there and what you need to do before, during, and after. I thought it was very beneficial because I was learning from step one.

Quinn viewed mathematics discussions as a step-by-step process consisting of specific phases and guidelines. She felt like she had to adhere to "a specific way of doing it."

Therefore, she focused on "how to implement" discussions rather than understanding why to implement them.

She especially valued elements of the MPD that provided her with feedback. This included classroom visits and analyzing videotaped lessons with the PD instructors. She acknowledged, "They gave me immediate feedback on how I could better my teaching" and helped her realize, "I need to fix that." These opportunities for reflection were viewed as ways to correct or "fix" teaching practices rather than opportunities to better understand student thinking and learn ways to respond to such thinking. Quinn placed more emphasis on procedural aspects of how to orchestrate discussions rather than why discussions were valuable for understanding student reasoning. She was so overcome with learning the practice for herself that she could not shift to focus on her students' learning. Pressures from multiple communities drove her to perfect the structural elements of LMD in order to fulfill school and district-level expectations.

Student outcomes. After implementing mathematics discussions in their classrooms, Danielle, Carol, and Katherine began to see evidence of student learning and success. Each teacher maintained that mathematics discussions led to improvements in students' engagement, collaboration, confidence, and mathematical understanding. Such successes and improvements were absent from Quinn's discourse. While Quinn was an active and eager participant in the MPD who often contributed to discussions, she did not discuss her students' learning as a result of LMD. When discussing successes related to learning, she focused on herself, describing improvements in creating mathematics

problems, developing specific learning targets, and crafting questions as she anticipated student responses.

Occasionally, Quinn referenced "growth" and even stated, ". . . we see it working" and it's "proven to be one thing that's really good for our kids . . ." However, she never specified the ways she saw her students' mathematical understanding grow or improve. She did not share evidence of her students' success or achievement as a result of implementing mathematics discussions. Her statements did not reflect concerns regarding students' mathematical thinking or reasoning. Once again she focused on her own learning, failing to appreciate her students' learning.

It was difficult for Quinn to acknowledge or recognize improvements in student learning, because she was confused as to whether this type of instructional model even contributed to student learning. She admitted not recognizing aspects of the discussion as "teaching" and stated, "I felt like there were some days that I needed to teach." Mathematics discussions did not become a part of her regular practice and were not integrated into her daily lessons. Therefore, Quinn was unable to recognize her student learning and successes as a result of such discussions.

Additionally, Quinn was frustrated with her students' performance on district and state assessments and did not believe discussions prepared her students for such tests. She stated, "I just feel like sometimes we focus a lot in Core Math on turning and talking and working with partners and that kind of stuff. I feel like our kids aren't quite prepared when they're given that abcd test." Her conception of learning was reduced to the

performance on a multiple-choice standardized test. Therefore, her failure to recognize her students' learning and achievement may have been due to such misalignment.

Differentiation. Danielle, Carol, and Katherine recognized the benefits of enacting the core practice of LMD. Mathematics discussions allowed the teachers to more effectively differentiate their instruction and meet the individual needs of their students. Unfortunately, Quinn's discourse did not reflect significant concerns regarding her students' individual learning needs. Instead, she focused on her own learning as she wrestled with overcoming the challenges of enacting the core practice. She focused on implementing the mechanics and structure of LMD rather than responding intentionally to her students' mathematical needs.

While she did acknowledge that mathematics discussions allowed her to more readily learn about her students' misconceptions, she was unable to modify her teaching in flexible and strategic ways to address such misunderstandings. She had difficulty responding to unanticipated errors and misconceptions because such responses deviated from her lesson plans and the lesson structure. For example, in one lesson, Quinn asked her students to show one-half on the geoboard. As the students shared and discussed several responses, Quinn posed several questions in a row. Once a response was given, she would move on to the next question or to another student without connecting or expanding on students' current ideas and strategies. It was apparent that she was unable to respond to her students' varying responses and misunderstandings. She felt comfortable asking her pre-planned questions, but was unable to modify the discussion based on the responses the students gave her. Strict adherence to her lesson plan

provided more security and less ambiguity, so Quinn continued to focus on the mechanics of leading discussions rather than adapt her instruction in response to her students.

Quinn's trajectory of participation differed from Danielle, Carol, and Katherine. Her discourse did not reflect a shift from self to student. She remained focused on her own learning and improvements and valued the practice for the organizational structure it provided to her mathematics lessons. Pressures and expectations from multiple communities, as opposed to improvements in student mathematical understandings, motivated her to enact a new instructional model. As a result, Quinn only participated peripherally and never reached full membership in the MPD community.

CHAPTER V

DISCUSSION

Grounded in a situated learning theory (Lave & Wenger, 1991), the previous analysis described and compared the participation of four teachers in a community of practice. These trajectories of participation provided coherent narratives of the interactive, social process of learning the teachers experienced while engaged in the MPD. Each trajectory offered insight into each teacher's learning of the core practice of leading mathematics discussions (LMD) and revealed specific aspects of their participation along the dimensions of meaning, practice, identity, and community, and described each teacher's journeys toward membership in the emerging community.

Wenger (1998) maintains that learning is not only the production of a social structure; it is also the production of identity. By actively participating in the world, we shape what we do and who we are. We develop communities and construct personal identities by engaging in certain activities with certain people. Therefore, learning is not just the acquisition of skills and information but is a transformative process of becoming. It involves an experience and formation of identity as one negotiates the meanings and experience of membership in social communities. Participation is an integral source of both learning and identity. Thus in discussing the findings, I use a lens of identity to better understand teachers' learning through their participation.

The previous chapter provided an empirical analysis of the teachers' social participation and experience of membership in the MPD community. As the teachers participated in the MPD, they forged new identities as they became a community. To provide a theoretical analysis of teachers' identity transformation, I use Wenger's (1998) three modes of belonging—engagement, imagination, and alignment—to frame the following section and explain the teachers' learning and identity formation. I conclude the chapter by relating my findings to existing research on teacher learning and offer implications for teacher educators, researchers, and policy makers.

Modes of Belonging

Wenger (1998) identified three distinct modes of belonging critical to the process of identity formation and learning. These mechanisms include engagement, imagination, and alignment. He maintained that all three are integral to learning. From this perspective, I argue that Danielle, Katherine, and Carol experienced each mode as they transformed their identities within the MPD community and created their unique, yet interacting, trajectories of participation that led to full participation in the MPD community and new identities for each teacher.

Engagement

Learners invest and contribute in a variety of interdependent ways as they engage in a learning community (Wenger, 1998). Active participation entails mutually engaging in shared activities, developing interpersonal relationships, and committing to a common enterprise. Although Danielle, Carol, and Katherine participated differently in the MPD, all three were engaged in the work of learning to LMD. Whether solving a challenging

mathematics problem, analyzing student work samples, or collectively watching videos of mathematics discussions, Danielle, Katherine, and Carol participated in the activities during the MPD and interacted with others in meaningful ways. Their participation led to shared commitments and relationships among the community members.

Throughout the MPD, it was apparent that these teachers valued opportunities to learn and work with one another. They respected the different perspectives, levels of knowledge, and years of experience offered by members of the community. They relied on each other for support and developed interpersonal relationships across the two schools. Danielle summed up the group's experience by saying, "We just melded so well together…We could do it because we've gone through everything." On the final survey, she wrote, "I also enjoyed the camaraderie between the two schools. I could go to anybody in Core Math II and knew they would listen to what I had to say and give suggestions." Danielle's statements were evidence of the strong bond established by the group. They formed a community and "melded so well together" because they recognized their own commitments and practice in others. Carol and Katherine shared similar opinions. Katherine regarded the community as "an asset," stating that it "made me more knowledgeable about how to teach math and how to help my students" and "broadened my horizons as far as being able to have more tools in my kit to help my children." Carol also welcomed and appreciated the support from her colleagues. In her words, "[there is] nothing better than learning from your peers."

Enacting a new instructional practice was challenging for all teachers. However, the community offered teachers support and guidance as they negotiated unfamiliar

situations. The community not only helped each teacher solve mathematics problems, but it also assisted them as they struggled with issues of enactment in the classroom. Danielle wrote, "It has been great to have other people support you through struggles that you may be having while trying to implement core math in your classroom." She described how everyone had strengths and areas to grow in their teaching, and how the MPD community provided her with support and ideas when she was having "a hard time" or "falling apart." Carol shared that working with teachers in different grade levels and opportunities to discuss common concerns with implementing discussions was critical to her learning. She stated, ". . . I could relate to whatever you were going through so that makes things easier for all of us." Similarly, Katherine explained, "We've built kind of a community amongst ourselves that we're able to, you know, discuss what we've learned and what we've used in our classrooms and how it's helped our students and what's worked and what hasn't worked." Participation in the emerging community provided them the tools, resources, and support to learn to lead mathematics discussions in their classroom. Over time, their history of shared experiences ultimately led to a commitment to the common enterprise of improving mathematics instruction.

Imagination

Imagination, Wenger's (1998) second mode of belonging, enables one to form new interpretations and adopt other perspectives. Exploration and creation allow one to experiment with possibilities and interpret situations in multiple new ways. Through this lens, I argue that another commonality among Danielle, Carol, and Katherine's trajectories of participation was the ability to imagine new possibilities for their teaching.

Though all three were recognized as accomplished teachers by their administrators, peers, and parents, they were open to try something bold and different in their teaching, despite years of experience and long histories of success. Both Katherine and Carol admitted struggling with re-centering their teaching around students' thinking. Katherine described it as a "whole flip for me" yet vowed to continue working to improve. Carol recognized her "gradual" and "ongoing process" as she struggled with this shift, but embraced, and even "loved," how building from students' ideas in discussions was "inviting," "career changing," "welcoming," and "encouraging." All three sought new experiences in order to expand their teaching repertoire. They came to the MPD to imagine new ways of helping their students learn.

Danielle, Katherine, and Carol were innovative and creative as they learned to lead discussions in their classroom. They experimented with a variety of mathematical problems, facilitated discussions in multiple ways, and were resourceful in responding to their students' specific needs. They were flexible and creative as they integrated discussion into their instructional routines and adapted the lessons to the needs of their students. Although comfortable with the launch, explore, and discuss lesson structure shared in MPD to support teachers in enacting the practice, Danielle felt comfortable deviating from that format. She asserted that her teaching became more strategic in order to help her students "grow mathematically." She readily admitted, "Re-launching is okay. Going back, it doesn't have to be in that order every time." Carol's confidence and imagination were evident when she stated, "So I think you just have to get used to whatever is right for me, what works for me, for my class, what works for my kids." All

three participants were able to imagine ways that their learning in the MPD could become a part of their teaching.

Alignment

The teaching profession involves coordinating multiple perspectives and communities, including school administrators, colleagues, parents, school districts, state and national agencies, as well as personal commitments to spouses, families, and communities. Teachers reconcile these different, often conflicting, perspectives daily to effectively meet the needs of their students. Wenger (1998) recognizes this work of reconciliation as alignment. Threaded throughout Danielle, Katherine, and Carol's trajectories of participation was a continuous effort to align the vision of the MPD with their current situation as they transformed their identities. Ultimately, they were able to connect their learning in the MPD to broader enterprises outside their classrooms, negotiate pressures in the midst of enacting a new instructional practice, and span community boundaries.

In efforts to support teachers in aligning their learning in the MPD with their other communities, the professional development was intentionally designed to involve administrators, curriculum specialists, and district leaders in the emerging community. A school-level lead teacher and instructional facilitator from both districts, as well as school principals, were participants. District leaders, including the Elementary Director and Math/Science Lead Teacher, planned and facilitated the MPD. Other district leaders, such as the Superintendent, Assistant Superintendents of Curriculum and Instruction, and

an Elementary Director also visited with the teachers, offering support and encouragement from the district level.

The teachers recognized and appreciated the support they received from these other communities as they integrated mathematics discussions into their teaching. Katherine described her administrators as being "very supportive" and "encouraging." Later in the year, her principal asked Core Math teachers to speak at a staff meeting to share their learning with others and encouraged others in the school to visit classrooms and observe mathematics discussions in action. Danielle shared a similar feeling of appreciation, calling her administrators involvement a "good thing" that allowed a better understanding of the changes she was endeavoring to make in her teaching. She stated, "From a teacher's prospective, it's really nice that we have our administration come in and hear about this stuff and understand when they come in our room that we're not just having a free for all." Similarly, Carol was grateful for the support and guidance offered by the facilitators, both curriculum leaders at the district-level, specifically citing assistance and availability for feedback. She commented, "I really think that made a big, big difference you being available for us." What began as a boundary encounter among the teaching, teacher educator, and school and district administrator communities grew into a community of practice in its own right. As a result, mutuality among members and shared meanings of mathematics discussions enabled Danielle, Carol, and Katherine to align their meanings across boundaries.

Additionally, Carol, Danielle, and Katherine connected and shared their learning to broader enterprises beyond their classrooms or the MPD setting. Carol collaborated

and planned with her grade level team to incorporate mathematics discussions around engaging student-centered problems into their weekly lessons. Katherine contributed to grade level planning, shared at school-level faculty meetings, and opened her classroom for visits and observations. Danielle shared her experiences with teachers throughout the school district during a district-wide professional development conference for elementary teachers. Each was not bound or restricted by the MPD community. They willingly and enthusiastically shared their learning across multiple communities, resulting in improved understandings of the value of mathematics discussions and coordinating enterprises between the two schools.

Though pressures for performance on district and state-level assessments and from parents not understanding mathematics instruction could have significantly challenged their learning, all three teachers were able to negotiate them as they implemented mathematics discussions in their classrooms. Carol, Danielle, and Katherine reported that they did not feel challenged or pressured by parents. Danielle shared, "To be perfectly honest, I didn't have a lot of trouble with parents this year . . ." Katherine made a similar comment, saying, "My parents have been pretty open and they've been, they've all been pretty satisfied with their children learning this year in math."

Similarly, pressures for performance on district and state-level assessments did not overwhelm Danielle, Katherine, or Carol. They saw the value of discussions and believed that their students would eventually be successful on various types of assessments. Based on their classroom evidence and day-to-day experiences, they saw

their students were learning and improving their mathematical understanding. Katherine was nonchalant about testing pressures, sharing that she did not allow assessments or performance data to cause her distress. She stated,

> Just make sure that you are giving your children what they need so that they're going to be able to be successful when we do have to do the benchmarks and we do have to have that data for the state and for the district to show that.

Carol and Danielle discussed assessment results with other members of the Core Math community. They all agreed that results might not be seen immediately after implementing discussions, but that understanding and learning would result in the long-term. In one instance, Danielle and Carol affirmed and extended another teacher's thought related to testing:

> Victoria: You don't always see results right away with what we're doing. It happens over time.
>
> Danielle: But that's the important part. It happens over time. You don't see it right away. So those first assessments at the beginning of the year where my class is bottoming out and everybody else is up here, that was frustrating for me as a teacher.
>
> Carol: But two, three months down the road they can pull it from back here and know.

Unlike Katherine and Carol, Danielle faced opposition on her grade level colleagues at her school. Two teachers, Danielle and Victoria, were members of the MPD community who regularly led mathematics discussions in their classrooms. However, their grade level colleagues (who were not a part of the MPD) were unwilling to attempt new instructional strategies or change her instruction. Danielle did not allow

their reluctance to dissuade her. In the MPD community, Danielle discussed her frustration with her grade level team by saying:

> . . . other people on our team were very, very difficult. I had a veteran teacher on my team and I had a first year teacher. First year teacher was more willing to try some things but didn't understand it and they had so many other things playing into being a first year teacher that it was a little overwhelming so it got cut. And I get that, I understand that. The veteran teacher, she had been teaching for so long and it worked for her that she couldn't see the value in what we were doing even talking through lessons and inviting her to come to our classroom and observe. It was just, oh no no that's good for you but I'm going to stick with what I'm comfortable with. That was very, very frustrating.

Although the process of alignment was somewhat challenging, and even frustrating at times, all three sought to reconcile different perspectives and expectations about mathematics teaching. They successfully negotiated tensions, established relationships across communities, and spanned boundaries as they transformed their identity through participating in the community.

Wenger (1998) maintains that the interplay of these three modes of belonging—engagement, imagination, and alignment—creates "a richer context for learning" (p. 217). I argue that Danielle, Katherine, and Carol's trajectories of participation led to full membership because they had a sense of belonging within the community and forged new identities. They identified with the Core Math community, yet understood their work within a larger context beyond the MPD setting and even their classroom. By adopting and negotiating new meanings across boundaries, and through coordinating and aligning the purpose of mathematics discussions, their trajectories led to transformations of their identities and the incorporation of LMD in their teaching.

Differences

Unlike the previous three cases, Quinn's trajectory of participation, characterized by misalignment and disparate meanings and enactment, never led to full participation and membership in the MPD community. While her participation exhibited an increase in confidence, established relationships in the community, and demonstrated attempts at enactment, her early progress was constrained by other communities of which she was a part. She was unable to resolve tensions between her existing practice and the emerging understandings of the MPD community or negotiate pressures from outside communities. I argue that Quinn, in the process of identity formation and learning, wrestled with alignment and imagination. As a result, her identity transformation did not enable a form of participation that led to learning, as was similar for the others.

While Quinn readily and willingly engaged in the MPD community and with the core practice of LMD, she was unable to align her existing practice with that of the community and unable to imagine it in her classroom. She could not reconcile pressures from different communities or move beyond the mechanics and structure of LMD to enact the practice with imagination and creativity. In the next section, I will describe her struggles with alignment and imagination, which ultimately constrained the formation of an identity that supported full participation in the community.

Alignment

Teachers encounter various perspectives and meanings as they seek to understand and improve their students' learning. Alignment requires a coordination of these multiple, and sometimes competing, perspectives in order to address significant and

challenging educational issues. Quinn found it difficult to resolve internal tensions related to her philosophies of teaching and manage external pressures associated with testing and parents. She was unable to reconcile disparate meanings or span boundaries across communities, thus creating conflict and struggle as she renegotiated her identity.

Throughout the MPD, Quinn struggled with reorganizing her instruction around students' mathematical thinking. Her existing practice characterized by traditional, teacher-directed methods was influenced by her past experiences and beliefs. It was vastly different from the one that emerged in the MPD and resulted in unresolved meanings of the purpose of mathematics discussions. She grappled with her role as a facilitator. The meanings she made of the instructional moves were increasingly different than those of the MPD community and at times she even disregarded LMD as teaching. This was evidenced by her contradicting statements of meaning and understanding which demonstrated that she was trying to make sense of the two opposing models. She acknowledged LMD was "best for our kids" and that students "need to learn from each other." However, she also made statements such as "I was like, where is my teaching coming in . . .'" and "I kept doing these student-centered learning activities but I felt like there were some days that I needed to teach . . ." Statements such as these suggest that Quinn did not find mathematics discussions meaningful in the context of teaching. She understood mathematics discussions to be an ancillary, rather than integral and integrated, part of her daily mathematics instruction. Her ongoing tensions were never resolved over the course of the MPD.

Another source of Quinn's misalignment was pressure from other communities, most prominently parents and district and school administration. Quinn admitted that parents were her "biggest struggle." They questioned her attempts at changing her practice and misunderstood her rationale for promoting alternative computational strategies over memorization and single, traditional algorithms. Pressure to perform on state and district assessments by administration was also difficult for Quinn to reconcile. She was ineffective at connecting her teaching to formal, standardized tests, causing students to be unprepared for such tests. Referring to these pressures as "constrictions," Quinn failed to resolve these conflicting perspectives as she tried to implement new instructional strategies.

Acknowledged by Wenger (1998) as "the most significant challenge faced by learners" (p. 160) yet critical for alignment, the work of reconciliation requires coordination and negotiation. Quinn not only found reconciliation challenging, but impossible, to realize. Parents, administrators, and the Core Math community defined competence in different ways. As a learner, Quinn could not find ways to balance these conflicting and competing perspectives. Demands to please parents and perform on district and state assessments overwhelmed her. As a result, she could not reconcile her multi-membership in various communities. I argue her lack of teaching experience and isolation exacerbated these tensions that ultimately did not lead to identity transformation. Similar to Danielle, Quinn was a beginning, novice teacher with only three years of teaching experience. But unlike Danielle, she was the only fourth grade teacher from McDonald Elementary participating in the MPD. Unlike the other teachers,

she did not have a grade level partner to offer support and assistance in dealing with the demands of both external and internal pressures. Therefore, I conjecture that the process of reconciliation and alignment remained a constant struggle for Quinn because she did not have a partnering colleague.

Imagination

While alignment entails connection and coordination, imagination involves creation and exploration (Wenger, 1998). Imagination enables one to form new interpretations, experiment with possibilities, and adopt other perspectives. It offers vision, expanding and broader images of the world, and fresh understandings related to a big picture. Imagination is an important ingredient for learning. Learning requires not only the acquisition of knowledge, but also the creation of knowledge. I argue that Quinn struggled to imagine what LMD could be as a part of her practice. Whereas Danielle, Carol, and Katherine transitioned from attending to the mechanics of leading discussions to its function for learning, Quinn's focus was predominately on the procedural aspects of the practice. Though her enactments demonstrated that she acquired the skills and structure associated with mathematics discussions, she was less successful with the more interactive and responsive aspects of discussions. Relating her learning from the MPD to her existing practice was a struggle for Quinn throughout the year.

Early in the MPD, Quinn focused on the mechanics, structure, and actions of LMD. In both her initial statements and interactions with other members of the MPD community, she questioned the aesthetics of discussions, such as clarity, classroom management, and other non-mathematical aspects. She admitted selecting student work

based on organization and neatness over mathematical understanding, struggling with sharing incorrect solutions, and motivating students to participate. Though these foci were similar to Danielle, Carol, and Katherine, they persisted throughout the MPD and remained a focus for Quinn. In her early classroom enactment, Quinn adhered closely to the organizational structure shared in the MPD which provided a way to manage the unpredictability of mathematics discussions. As a result, Quinn created specific learning targets, adapted mathematics problems to be more engaging and challenging, and formulated questions that were closely linked to her learning goals for students. When leading the discussion however, she struggled with the more contingent aspects of the practice. Her instructional moves were formulaic and did not build upon or connect students' mathematical ideas. For example, during a fraction lesson in which students showed one-half on the geoboard, Quinn fired off one question right after the other. Once a response was given, she would move on to the next question or to another student, failing to connect and expand on students' current ideas and strategies. She failed to modify the discussion or address her students' varying responses and misunderstandings. Unlike the less interactive moves one makes to prepare for a discussion, Quinn struggled with the in-the-moment instructional practices required when leading discussions. This included responding to students' mathematical thinking in ways that would advance her learning goals.

As the year progressed, discussions in Quinn's classroom did not advance like those in Danielle's, Carol's, and Katherine's classrooms. She avoided having students share non-routine solutions. When encountering unanticipated errors and misconceptions

when monitoring, she quickly corrected students directly rather than eliciting their thinking and responding in a way that would help students refine their thinking. In the MPD, Quinn reported that she found it challenging to integrate mathematics discussions into her daily instruction, understand her role as a facilitator, and respond to her students' varying understandings. Quinn's early understanding of the framework for leading discussions as prescriptive did not change as it did with other participants; consequently, the discussions she led were not productive for students' learning.

Quinn's learning in the MPD remained focused on herself as the MPD progressed; that is, rather than creating new meanings for the practice that were focused on students and their learning, she was unable to reimagine her practice like Danielle, Carol, and Katherine. She was unable to imagine mathematics discussions beyond a three phase structure or creatively integrate the core practice into her daily instruction. Her trajectory of participation was curtailed by her inability to reconcile multi-membership in her school community, and the transformation of her identity was not the same as other participants.

Summary

I maintain that three of the teachers, based on my analysis of their participation in the MPD community, became competent members of the community and formed identities compatible with high-quality mathematics teaching. A combination of engagement, imagination, and alignment inspired and shaped their learning. However, as this case study illustrated, Quinn had a very different experience. She failed to attain full

membership in the community and transform her identity. I believe this was because she was unable to develop an identity that allowed her to span multiple communities.

Danielle, Carol, and Katherine were full members in their school communities. This was evidenced by their participation and years of experience. They established themselves as leaders both on their grade levels and in their school and were well-respected by parents, colleagues, and administrators. They maintained identities of accomplished, successful teachers. As a result, they were able to develop a new identity in the MPD community where they worked together to understand and develop the practice of leading discussions. Their firm identity in their school communities allowed them to negotiate multi-membership and span boundaries across perspectives. Their multiple trajectories became a part of each other, forming a nexus of multi-membership that valued and reinforced student mathematics thinking and understanding.

However, Quinn had not yet established her identity in the school community. She was a novice teacher with only three years teaching experience. She was still developing her identity as a teacher and a member of her school community. She was not a full member in either settings—the school or the MPD. Therefore, her participation led to irresolution. Without a sense of belonging, she was thus unable to renegotiate new meanings of practice, fully participate in the community, and form an identity that enabled her to be a full member in the MPD community. This instability made it difficult, if not impossible, to experience multi-membership across communities. Therefore, she was unable to align and reimagine what her practice of leading discussions could be.

Revisiting the Literature

In Chapter II, I provided a review of the research literature related to teacher learning in professional development settings that focus on participation and changes in instructional practices. In this section, I return to collective participation and coherence and alignment and highlight connections to my findings.

Learning through Collective Participation

Collaborative participation is essential to effective professional development that aims to improve teacher learning and instructional practices (Cohen & Hill, 2001; Darling-Hammond & Richardson, 2009; Desimone, 2009; Garet et al., 2001; Hill et al., 2013; Loucks-Horsley & Matsumoto, 1999; Stein et al., 1999). Results of my study support this finding and further indicate that teachers benefit by participating in MPD in which strong learning communities have been established. Results from my study also indicated that teachers change their identities and instructional practice by learning, collaborating, and supporting one another. Similarly, Kazemi and Franke (2004) found that teachers' participation shifted as a result of their involvement in collaborative professional development. Shifts in participation provided evidence of teacher learning and changes in identity. My study adds to these findings by suggesting that as teachers' participation shifted from self to student, they were better able to learn and enact the practice of LMD and ultimately transform their identities. MPD must find ways to focus on student learning and help teachers shift the focus from themselves to their students.

Alignment

Professional development should be connected, coherent, and aligned with school and district goals in order to influence teacher learning and improve classroom practice. Similar to Jackson and Cobb's (2013) findings, my study also showed that by focusing on the same core practice of LMD, both communities understood and shared similar expectations for classroom instruction. By purposefully attending to alignment and coherence in this MPD, the teachers' understanding and enactments of the core practice improved. Heck et al.'s (2008) findings, suggested that when teachers were more likely to change their teaching practices when they believed that their administrator supported the reform efforts. My study adds further evidence that principal support is an important factor in influencing teacher learning and changing instructional practice. My study extends these results by showing the importance of alignment. Professional development must seek to align meanings associated with the intent and purpose of the instructional practices across communities. In order for teachers to attain full participation and change their instructional practice, meanings must be clearly articulated and aligned.

Implications and Further Research

The goal of this research was to investigate a case study of four teachers' learning of the core practice of LMD. The results indicated that trajectories of participation can offer ways to uncover specific understandings of teachers' learning of this core practice. This section highlights implications for professional development designers, researchers, and policy, school, and district leaders, as well as indicating future research needed in relation to trajectories of participation.

The findings from this study have implications for practitioners who design and implement MPD on instructional practice. My findings suggest that learning does not occur in isolation but involves a community that brings about the changes necessary for developing practices of high-quality mathematics teaching. It is recommended that teachers have a partner on a daily basis, preferably a grade level team member to participate jointly in the MPD. This allows teachers to discuss the meaning and implementation of the core practice and encourage one another to reach full membership in the community. A supportive colleague may have benefited Quinn as she struggled with differing instructional models, classroom enactment, and pressures from outside communities. My study also suggests a need for professional development facilitators to be cautious when judging participation. Non-observable participation does not equate to non-learning and observable participation does not equate to learning and understanding of the practice. Just as Katherine was initially a reserved and quiet participant, teachers in MPD may not appear to be participating. Misjudging this as a weakness or deficient in learning is erroneous.

The findings from this study have implications for researchers working on the core practice of LMD. My findings suggest trajectories of participation can offer ways to analyze teacher learning and teacher change as opposed to quantitative methods that are limiting in their analysis. Because learning is complex and influenced by multiple factors, studying trajectories of participation can provide researchers with a richer, more complete way to analyze teacher learning. By analyzing participation, researchers can gain a deeper understanding of how teachers make meaning, enact the practice, develop

an identity of the practice, and become an integral member of the community. Based on my analysis, I found that while all the teachers attended the same professional development, their trajectories of participation were vastly different and illuminated specific understandings. This analysis of discourse offered revealing insight into the teachers' learning of the core practice as well as their changing membership in the MPD community. The trajectories provided a descriptive narrative of the journeys of membership and learning.

Finally, results of this study also hold implications for policy, school, and district leaders when making decisions regarding MPD. Results indicate that careful attention should be given to differentiation in MPD. Just as students learn differently and instruction should be differentiated accordingly, teachers also learn differently. Expecting teacher learning to result from a "one size fits all" MPD program is naïve. As demonstrated in this study, teachers adopt new instructional practices when they have support that is tailored to their needs around their own students' learning. Until teachers can shift from their own personal learning to that of their students, this study suggests that the transformation of identity needed to make instructional change is unlikely. For example, Quinn valued the practice for the benefits it afforded her as a teacher, and she focused on her on progress as opposed to that of her students. This striking difference set Quinn apart from the other three teachers and resulted in an irresolved trajectory of participation. It is imperative that money and time be allocated to MPD opportunities that take place close to classroom practice and are tailored to meet the needs of teachers.

This will bring about significant shifts in the practice of teaching mathematics called on by decades of reform efforts.

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APPENDIX A

CORE MATH II MID-YEAR INTERVIEW

Core Math II Mid-Year Interview
February 2014

Part I: Introduction

1. Welcome participant and introduce yourself.

2. This interview is a part of the data collection for the Core Math II research grant. I will ask you several questions. Please respond openly and honestly. I will be recording the interview, and I will also take notes as you talk. The interview should take 30 to 40 minutes. If you have any questions throughout the interview, do not hesitate to ask. Thank you for your participation!

Part II: Communities

1. Describe the communities that you belong to as a teaching professional. (The term "communities" might not be familiar with participants. You may want to say, "For instance, some of the communities to which I belong are the math education community, the doctoral students at UNCG, and the Core Math Research Team.")

2. Do you feel a part of new communities as a result of Core Math? Do you feel like you have a different role in some of your existing communities as a result of Core Math? In what ways?

3. In what ways do you feel a part of the Core Math community? Can you tell me more about that? Can you give me specific examples of when you felt a part of the Core Math community? Can you give me specific examples of when you did not feel a part of the Core Math community?

Part III: Student-Centered Instruction

4. Describe how the Core Math community has helped you **learn about** student-centered instruction. Describe how the Core Math community has helped you **implement** student-centered instruction. How has your **school community** helped you implement student-centered instruction? How has the **school district** helped you implement student-centered instruction?

5. Describe any barriers you have faced in implementing student-centered instruction. How have the school, district, or state communities contributed to any of these barriers?

6. How has the Core Math Professional Development addressed any of the barriers or constraints to implementing student-centered instruction? If so, in what ways?

7. How do you negotiate (or deal with) pressures from school, district, state, and the parental community as you implement these new practices in your classroom? What has been helpful about the Core Math community in doing this? What more do you need?

8. How has the support from your administrators enabled you to implement student-centered instruction in your classroom and throughout the school? How has the Core Math community supported your administrators? In what ways has your lead teacher/instructional facilitator supported the implementation of student-centered instruction in your classroom and throughout the school?

9. In what ways has the school district supported or constrained your enactment of the Core Math professional development?

10. Describe the implementation of student-centered instruction in your school, particularly among the non-Core Math participants. What do you attribute the implementation (or lack of) to?

Part IV: Closure

1. Anything else that you would like to share?
2. Thank you for participating in the interview. I appreciate your time and input.

APPENDIX B

JOURNAL PROMPTS

Journal Prompts

Summer

Day 1

Reflect on today's math problem. Describe key components for the orchestration of the task.

Day 2

Identify factors that are important to consider when setting up a mathematics classroom that encourages student discourse and problem solving.

How has the environment effectively contributed to your learning?

How could the environment be improved to facilitate learning?

Day 3

What has been your biggest "take-away" from this week's PD?

How can Core Math II continue to support you? What are your areas of need?

Day 4

As you begin planning for this upcoming school year, how will you select and plan your mathematical tasks?

Fall

September

Share ways you have tried to implement a student-centered learning environment.

What challenges or obstacles have you faced?

October

Reread your journal entry on July 31 - describing traditional verses student-centered classrooms.

Write a new journal entry explaining how you would now define a student-centered classroom. Please be specific.

December

Record a classroom discussion.

Watch and evaluate your discussion using the Discussion Reflection.

Winter

January

Share recent ways you have tried to implement a student-centered learning environment.

Describe your successes and things you are proud of.

What challenges or obstacles are you facing?

APPENDIX C

FINAL CORE MATH II SURVEY

Final Core Math II Survey
June 2014

1. Describe how being a member of the Core Math community has benefitted you.

2. Rate your participation as a member of the Core Math community on a scale of 1-10 with 10 being the highest rating. Describe your participation in Core Math.

3. What are the three most important or most helpful things you learned in Core Math II?

4. What were the most effective elements of this professional development?

5. Describe the benefits of each phase of the Core Math II PD:
   - Phase 1: Learning ABOUT SCI (traditional setting last summer)?
   - Phase 2: Learning FROM students (practicing with afterschool students)?
   - Phase 3: Learning IN practice (support implementing with your students)?

6. Please rate the following (10 being the highest):
   - Your understanding of student centered mathematics instruction.
   - Your understanding of discourse talk moves.
   - Your implementation of student centered mathematics instruction.
   - Your comfort level leading professional development about student centered mathematics instruction within your school or the district.

APPENDIX D

FINAL CORE MATH II FOCUS GROUP INTERVIEW

Final Core Math II Focus Group Interview
June 2014

1. Reflecting back on your Core Math II experience, how has Core Math II helped you learn about student-centered instruction? How has it helped you implement student-centered instruction?

2. Describe how being a member of the core math community has benefitted you.

3. What challenges have you faced in communicating student-centered instruction to others outside of your community?

4. Rate your participation as a member of the Core Math community on a scale of 1-10 with 10 being the highest rating. Describe your participation in Core Math.

5. What are the three most important or most helpful things you learned in CMII?

6. What were the most effective elements of this professional development?

7. What does it mean for you to be a teacher leader and advocate for student-centered instruction?

8. If you could sum up your Core Math experience in one word/phrase, what would that be and why?

9. Describe the benefits of each phase of the Core Math II PD:
   - Phase 1: Learning ABOUT SCI (traditional setting last summer)?
   - Phase 2: Learning FROM students (practicing with afterschool students)?
   - Phase 3: Learning IN practice (support implementing with your students)?