

EXAMINING MATHEMATICS COACHES IN SUPPORTING TEACHERS
TO DEVELOP AMBITIOUS INSTRUCTIONAL PRACTICES:
A THREE-PAPER DISSERTATION INVESTIGATING
CONTEXT, KNOWLEDGE, AND PRACTICE

By

Lynsey Kay Gibbons

Dissertation

Submitted to the Faculty of the
Graduate School of Vanderbilt University
in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in

Learning, Teaching and Diversity

August, 2012

Nashville, Tennessee

Approved:

Paul A. Cobb

Leona Schauble

Marcy Singer-Gabella

Thomas M. Smith

For Michael, who continually provides inspiration, support, and encouragement

ACKNOWLEDGEMENTS

This dissertation and the work leading up to it would not have been possible without the support of many individuals. I owe a special thank you for the guidance and continued support of Dr. Paul Cobb. I have learned to be a more critical researcher and thinker by engaging in many conversations with him. Thank you to Dr. Leona Schauble, Dr. Marcy Singer-Gabella, and Dr. Tom Smith for their feedback and contributions. I have learned to be a more effective writer by working with these professors. To Emily Shahan, I am grateful for her contribution to my development as a mathematics educator and researcher. To Dr. Tricia Browne-Ferrigno, Dr. Erin Henrick, Dr. Kara Jackson, and Dr. Chuck Munter, who have inspired me academically, professionally, and personally.

To my colleagues and friends, Annie Garrison and Glenn Colby, thank you for being there and enjoying life with me whenever possible—your support continually uplifted me. Thank you to the Teaching and Learning cohort who provided friendship, laughter, and sustenance. To others on the MIST project, I appreciate the scholarly conversations in which we engaged. To other friends—especially Jackie, Marie, and Sara—who provided valuable insight and comic relief.

To my family, I am especially indebted. My two amazing grandmothers, Alice and Olive, provided love and continually reminded me of the significance of life. My parents have always encouraged me and fostered a love of learning. My two amazing sisters and best friends, Leila and Meridith, have supported me in numerous ways throughout this journey. My in-laws have provided continuous support. And finally, my remarkable husband who amidst his own rigorous training, found time to inspire and encourage me through his unwavering support.

TABLE OF CONTENTS

	Page
DEDICATION.....	ii
ACKNOWLEDGEMENTS.....	iii
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
Chapter	
I. INTRODUCTION.....	1
II. EXAMINING PROFESSIONAL LEARNING LITERATURE TO IDENTIFY POSSIBLE PRODUCTIVE ACTIVITIES.....	6
Introduction.....	6
Overview of Analysis.....	10
Methods.....	10
Findings.....	16
Discussion.....	44
References.....	47
Appendices.....	62
III. HOW ASPECTS OF THE SCHOOL SETTING AND COACH CHARACTERISTICS INFLUENCE COACH CENTRALITY.....	66
Introduction.....	66
Methods.....	78
Findings.....	84
Discussion.....	101
References.....	106
Appendices.....	112
IV. EXAMINING PROFESSIONAL VISION FOR COACHING AND RELATED PRACTICES.....	121
Introduction.....	121
Overview of Analysis.....	128
Methods.....	130
Findings.....	138

Discussion.....	154
References.....	160
Appendices.....	167

LIST OF TABLES

Table	Page
1. Characteristics of Effective Professional Learning Opportunities.....	14
2. School Teacher Counts and Measures of Centrality.....	85
3. Measures of Expertise for Mathematics Coaches.....	87
4. Years of Experience.....	90
5. Information about Teacher Collaborative Meetings.....	94

LIST OF FIGURES

Figure	Page
1. Initial List of Activities Identified to Examine Against Characteristics of Professional Learning Opportunities.....	63
2. Search Terms Used To Identify Professional Learning Studies that Examined Specific Activities.....	65
2. School Sociogram of Mathematics Teacher Networks.....	111

CHAPTER I

INTRODUCTION

In order to implement instructional practices currently recommend by the National Council of Teachers of Mathematics (NCTM, 2000) and others in mathematics education research (e.g., Franke, Kazemi, & Battey, 2007; Kilpatrick, Swafford, & Findell, 2001), teachers need a qualitatively different and significantly deeper understanding of mathematics and student reasoning than most teachers currently possess (Ball, 1989, 1996; Cohen & Ball, 1990; Schifter, 1998; Stein, Grover, & Henningsen, 1996). Developing these practices requires considerable learning and changes in deeply held beliefs, knowledge, and habits of practice on the part of practicing teachers (Stein, Smith, & Silver, 1999; Thompson & Zeuli, 1999). Therefore, substantial support is required for teachers to develop such practices. One way to provide such support is through content-focused coaching, which is the focus of this dissertation.

Across the United States, many school districts are directing significant resources to content-focused coaching as a primary strategy for providing professional development for teachers (Coburn & Russell, 2008; Darling-Hammond, Wei, Andree, Richardson & Orphanos, 2009; McLaughlin & Talbert, 2006; Neufeld & Roper, 2003; Poglinco, Bach, Hovde, Rosenblum, Saunders & Supovitz, 2003). Theoretically, mathematics coaching appears to be a promising approach to supporting teachers' learning and professional growth; coaches can provide on-site, job-embedded training in which teachers co-participate with someone who has expertise in mathematics instruction. However, very

few empirical studies have been conducted that investigate content-focused coaching, and even fewer have focused on mathematics coaching.

A few studies have examined whether content-focused coaching works to improve the quality of instruction or to raise student achievement, but the results are mixed (Campbell & Malkus, 2011; Cantrell & Hughes, 2008; Gamse, Jacob, Horst, Boulay, & Unlu, 2008; Marsh, McComb, Lockwood, Martorell, Gershwin, & Naftel, 2008; Matsumura, Garnier, & Resnick, 2010; Ross, 1992; Sailors & Price, 2010; VanKeer & Verhaeghe, 2005). Variable implementation in the amount and type of coaching that teachers receive is one reason why the research evidence is mixed (Coburn & Russell, 2008; Matsumura, Sartoris, Bickel, Garnier, 2009). Therefore, it is important to understand the phenomenon of coaching and the process by which coaching works to support teachers' development of ambitious practices that will provide richer opportunities for student learning. The three studies address gaps in the current literature on content-focused coaching. First, it is essential to identify the types of activities that can support teachers' learning and development of ambitious instructional practices. Second, there is a need for richer understandings of what influences teachers to go to their coaches for advice or information about teaching mathematics. Finally, it is necessary to better understand what types of expertise coaches need in order to support teachers' learning and development.

The current literature on mathematics coaching gives very little guidance on what types of activities coaches and teachers should do together in order to support teachers' learning and development of ambitious instructional practices. When researchers propose types of activities, they rarely justify why the activities might be productive in

supporting teacher learning. Therefore, the goal of the first study was to identify types of activities that are likely to support teachers' development of high quality instructional practices. In the first paper, I conducted a conceptual analysis of the potential value of different types of activities in terms of the learning opportunities they provide for teachers to develop deeper understandings of mathematics, student reasoning, and ambitious instructional practices. These activities can take place between coaches and individual teachers or with groups of teachers. Because of the lack of attention to this issue in the coaching literature, I drew from what the fields of teacher learning and professional development have uncovered about teacher learning to assess the potential value of each activity. The identification of these activities contributes to our understanding of effective coaching practices by identifying potentially productive activities in which mathematics coaches and teachers can engage that are likely to support teachers' development.

In order for coaches to engage in potentially productive activities with teachers, it is important to understand what aspects of the school setting support coaches to be accessible to teachers. Because coaching policies and programs appear to be vulnerable to the same contextual complexities as other educational reforms (Coburn, 2001, 2006; Coburn & Stein, 2006; Matsumura, et al., 2009), it is important to understand what influences coaches to become a central source of expertise. In the second study, I worked with a colleague¹ to investigate what influences the extent to which mathematics coaches

¹ The second paper is a mixed methods collaboration in which Annie Garrison assisted in the quantitative analysis that informed the case selection. I took the intellectual lead on the paper; however, Annie contributed by co-conducting the centrality analysis to classify which coaches in our sample were central. Annie also contributed to the writing, including the explanation of how we calculated centrality indices in the methods section. Additionally, she wrote the corresponding methods/findings of the analysis of

are central within teachers' social networks. We analyzed social network data and conducted an in-depth case analysis of seven participating coaches from a large, urban district. The goals in doing so were to both uncover aspects of the school-level contexts that influenced how the coaching design was implemented, and to clarify what influenced teachers' decisions about whether to seek advice from a coach. This study can inform district leaders as they implement and refine content-focused coaching programs, including the refinement of the responsibilities of coaches, the role of school leaders in supporting coaches, and considerations for how district leaders can provide assistance.

The third paper is an exploratory study that investigated what, in addition to being relatively accomplished teachers, mathematics coaches need to know and be able to do in order to engage teachers in activities that are likely to support their development of high quality instructional practices. The study focuses on one school-based middle-grades mathematics coach who was identified as a central source of expertise in the second study. Using the list of potentially productive activities identified in the first study, I found that over four years she consistently engaged teachers in potentially productive activities. By examining a single case in depth, I was able to identify important practices and knowledge that allowed the coach to provide high quality individualized support to teachers. This study identified conjectures to examine in future research that considers what mathematics coaches need to know and be able to do to support teachers' development. By identifying what constitutes good coaching practices we can further consider the types of professional learning opportunities coaches need.

measures of expertise. Finally, she read multiple drafts of the paper and suggested changes to wording and ordering of the findings and discussion sections.

In sum, I seek to understand how mathematics coaching can support mathematics teachers' development of ambitious practices that will provide richer opportunities for students' learning. Together, these three interrelated studies constitute a significant step towards this goal and contribute to the field of research on content-focused coaching. These studies: delineated a range of coaching activities that have the potential to support teachers' learning; examined conditions necessary for coaches to become central to teachers' social networks in schools in order to support all teachers' improvement of their instructional practices; and explored knowledge and practices coaches need to support teachers' development of ambitious instructional practices. In addition to research contributions, these studies have pragmatic implications as the findings can assist district leaders in implementing or revising current school-based coaching designs.

CHAPTER II

EXAMINING PROFESSIONAL LEARNING LITERATURE TO IDENTIFY POSSIBLE PRODUCTIVE ACTIVITIES

Introduction

Teachers' development of ambitious instructional practices requires a qualitatively different and significantly deeper understanding of mathematics and student reasoning than most teachers currently possess (Cohen & Ball, 1990; Ball, 1989, 1996; Stein, Grover, & Henningsen, 1996; Schifter, 1998). Therefore, it requires considerable learning and changes in deeply held beliefs, knowledge, and habits of practice on the part of practicing teachers (Stein, Smith, & Silver, 1999; Thompson & Zeuli, 1999). The current literature on content-focused coaching claims that coaching is a potentially productive way to provide ongoing professional development to teachers (Poglinco, Bach, Hovde, Rosenblum, Saunders & Supovitz, 2003; Neufled & Roper, 2003). However, that literature gives very little guidance on what types of activities coaches and teachers should do together in order to support teachers' development of ambitious instructional practices. Furthermore, when researchers propose types of activities, they rarely justify why the activities might be fruitful to support teacher learning. The goal of this study is to identify types of activities that, when engaged in by teachers and mathematics coaches, are likely to support teachers' development of high quality instructional practices.

In this paper, I report the results of a conceptual analysis that illuminates the potential value of different types of activities in terms of the learning opportunities they

provide for teachers to develop ambitious instructional practices. These activities can take place between coaches and individual teachers or with groups of teachers. Because of the lack of attention to this issue in the coaching literature, I draw on what the fields of teacher learning and professional development have uncovered about teacher learning to assess the potential value each activity.

Supporting Teachers' Development of Ambitious Practices

High quality Mathematics Instruction

Over the past two decades, the National Council of Teachers of Mathematics (NCTM) has proposed ambitious goals for students' mathematical learning and mathematics teaching (NCTM, 1989, 1991, 1995, 2000). The *Standards* propose goals that include students' development of: 1) conceptual understanding and procedural fluency in a range of mathematical domains, 2) creation of multiple representations (including using and making connections between representations), 3) increasingly sophisticated forms of mathematical argumentation in order to communicate mathematical reasoning effectively, and 4) a productive disposition towards mathematics (US Department of Education, 2008; Kilpatrick, Swafford & Findell, 2001; NCTM, 2000; Lappan, 1997). These goals for students' learning have led to new conceptions of teachers' work (Lampert, Beasley, Ghouseini, Kazemi, & Franke, 2010; Lampert & Graziani, 2009).

This work is challenging as the goals for student learning are demanding (Kazemi, Franke, Lampert, 2009). This vision for instruction has been referred to as

ambitious teaching (Lampert & Graziani, 2009; Lampert et al., 2010). Ambitious teaching requires that teachers teach in response to what students do as they engage in solving challenging tasks, while holding students accountable to learning goals (Kazemi, Franke, & Lampert, 2009). Recent research in mathematics education has begun to delineate a set of instructional practices that support students' development of mathematical ideas (Franke, Kazemi & Battey, 2007; NCTM, 2000). Such practices include teachers supporting students to solve cognitively demanding tasks (Stein, Smith, Henningsen, & Silver, 2000), which is achieved by first making the task accessible to all students (Boaler & Staples, 2008; Hiebert, Carpenter, Fennema, Fuson, Wearne, & Murray, 1997). Next, while students solve the task, teachers assess students' understanding of the key mathematical ideas and attempt to advance their understanding by asking questions about their mathematical reasoning (Smith, Bill, & Hughes, 2008). Teachers then orchestrate a whole class discussion in which they press students to provide evidence and justification for their reasoning, and to make connections between their own and peers' solutions (Staples, 2007; Chapin, O'Conner, & Anderson, 2003).

Developing these instructional practices requires considerable learning on the part of practicing teachers, most of who learned to teach under a different paradigm (Stein, Smith, & Silver, 1999). Therefore, substantial support is required for teachers to develop such practices. One way to provide such support is through content-focused coaching. Below I define content-focused coaching and describe the current state of the literature.

Mathematics Coaching as a Form of Professional Development

As a part of their instructional improvement efforts, many districts currently implement content-focused coaching designs as one of the main mechanisms for supporting teachers' development of ambitious mathematical practices (Darling-Hammond, et al., 2009). Mathematics coaching is intended to provide on-site, job embedded professional development in which teachers work with someone who has expertise in mathematics instruction. Findings of several recent studies indicate the importance of co-participation of teachers with an accomplished colleague in activities that are close to practice is likely to support teachers' development of ambitious practices (Borko, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Wilson & Berne, 1999). Content-focused coach designs can be viewed as a form of apprenticeship in which less proficient teachers are expected to work with more accomplished teachers—the coaches (Collins, Brown & Newman, 1989; West & Staub, 2003).

Theoretically, content-focused coaching appears to be a potentially promising approach for supporting teachers' learning because the activities in which teachers engage with a coach can be directly relevant to the teachers' classroom practice (Coburn & Russell, 2008; Neufeld & Roper, 2003; Poglinco, et al., 2003). However, little empirical research exists on content-focused coaching, and even less on mathematics coaching in particular. Some research has focused on whether content-focused coaching works to improve student achievement or use of specific instructional strategies, but the results are mixed (Campbell & Malkus, 2011; Cantrell & Hughes, 2008; Gamse, Jacob, Horst, Boulay, & Unlu, 2008; Marsh, McComb, Lockwood, Martorell, Gershwin, & Naftel, 2008; Matsumura, Garnier, & Resnick, 2010; Ross, 1992; Sailors & Price, 2010;

VanKeer & Verhaeghe, 2005). Other research has examined the conditions in which content-focused coaching can be successful in supporting teacher learning (see for example, Cantrell & Hughes, 2008; Coburn & Russell, 2008; Gibbons 2012b; Mangin, 2005, 2007; Matsumura, Sartoris, Bickel, & Garnier, 2009). Although the latter studies have identified important aspects of school and district contexts that influence the effectiveness of coaching, these studies have typically not investigated the learning opportunities provided by coaches.

Overview of Analysis

Given the limitations of the coaching research, I conducted a conceptual analysis using the teacher learning and professional development literatures in order to determine the extent to which different types of activities might be productive in supporting teachers' development of ambitious instructional practices. As will be explained in more detail, I first developed a list of characteristics that have been shown in literature to be important in supporting teachers' learning. These characteristics for professional learning then allowed me to identify a set of activities that might be potentially productive. I then reviewed the relevant empirical evidence to clarify how a high quality enactment of each activity supported teachers' development.

Characteristics of Effective Professional Learning Opportunities

Over the last two decades, researchers who have investigated the professional learning of teachers have made substantial progress in identifying the conditions under which teacher learning takes place and the type of activities that provide opportunities for

teachers to develop practices that aim at ambitious learning goals for students (Ball, Sleep, Boerst & Bass, 2009; Darling-Hammond et al., 2009; Kazemi & Hubbard, 2008; Putnam & Borko, 2000; Wilson & Berne, 1999). In order to identify characteristics of effective professional learning opportunities, I first examined seminal literature reviews on professional development (Darling-Hammond et al., 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kazemi & Hubbard, 2008; Putnam & Borko, 2000). From these reviews, I conducted a literature search to identify additional studies that examined how teachers' are supported to develop ambitious practices. The review of literature resulted in the identification of nine characteristics of effective professional learning opportunities (see Table 1).

The first four of the nine characteristics focus on what learning opportunities should entail. The first characteristic is professional learning opportunities should *be intensive and ongoing* (Darling-Hammond, et al., 2009; Kazemi & Hubbard, 2008; Gallucci, 2008; Hill, 2007; Stein, Smith, Silver, 1999; Little, 1982). Ongoing and intensive learning opportunities allow teachers the time for serious, cumulative study of the given subject matter and time to try out ideas in the classroom and reflect on the results (Darling-Hammond et al., 2009). The second characteristic is that learning opportunities need to *be integrated into teachers' daily work lives and be relevant to the problems they encounter* (Darling-Hammond & McLaughlin, 1995; Gallucci, 2008; Hill, 2007; Franke & Kazemi, 2004; Franke, Kazemi, & Battey, 2007; Ingvarson, Meiers, & Beavis, 2005; Kazemi & Hubbard, 2008; Little, 1982; Putnam & Borko, 2000; Stein, Smith & Silver, 1999). The third characteristic is that the learning opportunities should *be aligned with curriculum materials and teachers' instructional goals for student*

learning (Hill, 2007; Kazemi & Franke, 2004; Kazemi & Hubbard, 2008; Little, 1993). When these characteristics are combined, there is a greater chance of influencing teachers' instructional practices (Cohen & Hill, 2001; Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet et al., 2001; Knapp, 2003; Supovitz, Mayer & Kahle, 2000). The fourth characteristic is that professional learning should *focus both on pedagogies of investigation and pedagogies of enactment* (Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009; Grossman & McDonald, 2008). Pedagogies of investigation involve analyzing and critiquing representations of practice, such as student work or video-cases of classroom instruction. Pedagogies of enactment involve planning for, rehearsing, and enacting high-leverage practices in graduated sequence of increasingly complex settings, such as setting up a mathematics task in front of a group of colleagues. Grossman and colleagues argue that both are necessary for teachers to develop ambitious forms of practice (Grossman et al., 2009; Grossman & McDonald, 2008).

The next three characteristics consider the importance of teachers working with others on developing their practice. The fifth characteristic of professional learning opportunities is to give teachers *opportunities to work with a more knowledgeable other* (Borko, Koellner, & Jacobs, 2011; Elliott, Kazemi, Lesseig, Mumme, Carroll & Kelley-Peterson, 2009; Borko, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Wilson & Berne, 1999). Studies of teachers' professional relationships show that teachers' access to expertise is associated with instructional improvement (Frank, Zhao & Borman, 2004; Penuel, Riel, Krause & Frank, 2009). Furthermore, Coburn and Russell (2008) argue that teachers are supported to learn when the more knowledgeable other routinely

presses them on key questions or issues (e.g., identifying the key mathematical ideas in a given task).

The sixth characteristic is that professional learning opportunities should aim to *develop teacher communities of professional practice* (Cobb, Zhao, & Dean, 2009; Darling-Hammond et al., 2009; Horn & Little, 2010; Kazemi & Hubbard, 2008; Little, 1993; Stein, Smith & Silver, 1999; Wilson & Berne, 1999). Research shows that productive working relationships among teachers and their colleagues have benefits that can include greater consistency in instruction, more willingness to share practices and try new ways of teaching, and more success in solving problems of practice (Horn & Little, 2010; Louis, Marks, & Kruse, 1996; McLaughlin & Talbert, 2006). Related to this, the seventh characteristic is learning opportunities that aim to *cultivate a professional discourse* (Ball & Cohen, 1999; McLaughlin & Talbert, 1993; Putnam & Borko, 2000). Lortie (1975) described the lack of technical language in teaching. Technical language is important to cultivate in order for teachers to have thoughtful discussions. These types of discussions are a valuable vehicle for analysis, criticism, and communication of ideas, practices, and values (Ball & Cohen, 1999).

The last two characteristics are concerned with the larger context of teachers' work and additional learning opportunities. The eighth characteristic is that the professional learning opportunities should *provide follow-up on formal professional development activities in teachers' classrooms* (Ball, 1996; Guskey, 2000; Garet, et al., 2001; Putnam & Borko, 2000; Spillane, Reiser, & Gomez, 2006). The provision of support in teachers' classrooms allows them to receive assistance while attempting to enact instructional practices they have learned about during formal professional

development opportunities. The ninth characteristic is that professional learning opportunities need to *form a coherent part of a wider set of opportunities for teacher development that align with school improvement goals and take into account the local context* (Borko & Putnam, 2000; Cobb & Jackson, 2011; Darling-Hammond et al., 2009; Garet et al., 2001).

Table 1	
<i>Characteristics of Effective Professional Learning Opportunities</i>	
Be intensive and ongoing	Darling-Hammond, et al., 2009; Kazemi & Hubbard, 2008; Gallucci, 2008; Hill, 2007; Stein, Smith, Silver, 1999; Little, 1982
Be integrated into teachers' daily work lives and relevant to the problems that they encounter in practice	Kazemi & Hubbard, 2008; Gallucci, 2008; Hill, 2007; Franke & Kazemi, 2004; Franke, Kazemi, & Battey, 2007; Ingvarson, 2005; Putnam & Borko, 2000; Stein, Smith & Silver, 1999; Darling-Hammond & McLaughlin, 1995; Little, 1982
Be aligned with curriculum materials and instructional goals	Hill, 2007; Kazemi & Franke, 2004; Little, 1993; Kazemi & Hubbard, 2008
Work with a more knowledgeable other who routinely presses teachers on key issues	Borko, Koellner, & Jacobs, 2011; Elliott et al., 2009; Coburn & Russell, 2008; Borko, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Wilson & Berne, 1999
Focus on pedagogies of investigation and pedagogies of enactment	Grossman et al., 2009; Grossman & McDonald, 2008
Aim to develop teacher communities of professional practice	Horn & Little, 2010; Cobb, Zhao, & Dean, 2009; Darling-Hammond et al., 2009; Kazemi & Hubbard, 2008; Stein, Smith & Silver, 1999; Wilson & Berne, 1999; Little, 1993
Cultivate a professional discourse	Putnam & Borko, 2000; Ball & Cohen, 1999; McLaughlin & Talbert, 1993
Follow up on formal professional development activities in teachers' classrooms	(Spillane, Reiser, & Gomez, 2006; Guskey, 2000; Garet, et al., 2001; Putnam & Borko, 2000; Ball, 1996)
Form a coherent part of a wider set of opportunities for teacher development that align with school improvement goals and takes into account the local context	(Cobb & Jackson, 2011; Darling-Hammond et al., 2009; Garet et al., 2001; Borko & Putnam, 2000)

Identification and Analysis of Activities

The second step in the conceptual analysis involved identifying types of activities in which coaches might engage teachers. These activities can take place between coaches and groups of teachers or with individual teachers. To identify relevant activities, I examined the following bodies of literature: professional development, professional learning (including teacher learning), teacher education, and content-focused coaching. I began by mining the reference lists of seminal literature reviews to identify potential activities (Darling-Hammond et al., 2009; Garet et al., 2001; Kazemi & Hubbard, 2008; Putnam & Borko, 2000). In order to cast a larger net, I also searched databases² for the term “professional development activities” and identified 23 activities (see Appendix A); I then used the characteristics for professional learning (see Table 1) to narrow to a set of potentially productive activities. In other words, each type of activity was judged against the criteria to determine its potential productivity.

Some of the activities were excluded because they did not match one or more of the nine characteristics. For example, an activity that has been used as a professional development activity is a book study. While a book could provide teachers with interesting information and provide fodder for conversation that may cultivate a professional discourse, it is not likely to provide opportunities to enact specific instructional practices. Another example of an activity that was excluded was action research. In this activity, teachers typically identify a problem for which they want to find a solution. While action research could identify a problem with one’s instructional practices, the activity structure is generally one that a teacher does individually—without

² The databases I used to search for literature include: ERIC, Education Full Text, Google Scholar, ProQuest Dissertations

the assistance of a more knowledgeable other—and it is generally not an activity that is ongoing. On the other hand, the remaining activities had the potential to match all of the characteristics: doing mathematics, examining student work, analyzing classroom video, rehearsing aspects of practice, co-teaching, modeling, and observing instruction and debriefing challenges of implementation.

Given that the focus of my analysis is to identify activities that have the potential to support teachers' learning and development of ambitious instructional practices, I then searched databases for studies related to the seven activities in order to identify studies that reported the types of teacher development that took place as a result of engaging in each type of activity (for a list of search terms I used for each activity, see Appendix B). I also looked for studies that allowed me to understand what teachers learned from engaging in the activity, as evident by change in participation or practice. Additionally, I looked for studies that clarified how facilitators supported the implementation of the activity. The results of this analysis are reported below.

Findings

From my in-depth examination of the professional learning literatures, I have identified seven activities that when engaged in productively by teachers and mathematics coaches (the more knowledgeable other) are likely to give rise to substantial learning opportunities for teachers and assist them in developing ambitious instructional practices. Activities that coaches might conduct with groups of teachers include: (a) doing mathematics, (b) examining student work, (c) analyzing classroom video, and (d) rehearsing aspects of practice. Activities that coaches might conduct with individual

teachers include: (e) co-teaching, (f) modeling, and (g) observing instruction and debriefing challenges of implementation. In the following, I draw on the literature to examine what teachers might learn as they engage in each type of activity, what makes the activity potentially productive, and what the facilitator might do during the activity.

Activities Conducted With Groups of Teachers

Doing Mathematics

As described earlier, ambitious instruction requires teachers to implement high-level tasks and orchestrate discourse that builds on students' reasoning and supports their understanding of significant mathematical ideas (Stein, Smith, & Silver, 1999; Lappan & Ferrini-Mundy, 1993). Teachers' ability to make mathematics accessible to and learnable by all students depends partly on their own mathematical knowledge (Suzuka, Sleep, Ball, Bass, Lewis & Thames, 2010). Hill and colleagues have found that the quality of teachers' mathematical knowledge for teaching plays a significant role in the effectiveness of their instruction and student learning opportunities (Hill, Rowen, & Ball, 2005). Research on teacher learning has highlighted the importance of doing mathematics as a professional development activity in order to support teachers to: (a) develop mathematical knowledge for teaching (Ball, Thames, & Phelps, 2008; Borko, Jacobs, & Koellner, 2011; Campbell & Elliott, 2011; Elliott, et al., 2009; Lo, Grant, & Flowers, 2008; Suzuka et al., 2010), (b) develop new conceptions of doing mathematics (Borko, 2004; Kazemi, Elliott, Hubbard, Carroll, & Mumme, 2007; Simon & Schifter, 1991; Schifter & Simon, 1992; Schifter & Fostnot, 1993; Schifter, 1998), and (c) develop

new instructional practices that incorporate students giving mathematical explanations and justifications (Borko, Frykholm, Pittman, Eiteljorg, Nelson, Jacobs, Koellner, & Schneider, 2005; Clark & Borko, 2004).

Because the activity of doing mathematics in the context of formal professional development has been identified as important in supporting teachers' development of ambitious practices, researchers of professional development have begun to investigate what facilitators need to know and be able to do in order to productively support teachers (Borko, Koellner, & Jacobs, 2011; Elliott, et al., 2009). Based on analyzing their own role as professional development facilitators and experiences with supporting facilitators, these researchers indicate the importance of facilitators preparing for professional development sessions by identifying goals for doing mathematics with teachers that are mathematically worthwhile, and selecting tasks that are relevant for a particular group of teachers (Borko, Koellner, & Jacobs, 2011; Elliott et al., 2009). Once selected, teachers engaged with the task for a period of time and then facilitators elicited teachers' varying solutions and invited teachers to question one another. Elliott and colleagues (2009) found that in productive discussions, facilitators intentionally "slowed down" teachers' conversations to explicitly engage in important mathematical ideas. They also found that facilitators supported teachers' learning by pressing teachers for explanations and justifications. Justifying why and how particular methods work helps to deepen teachers' understandings of mathematical ideas, which develops mathematical knowledge for teaching (Elliott et al., 2009). In order to support teachers understanding of ambitious instructional practices, facilitators stepped back and made explicit what they were doing as facilitators in pressing teachers for justifications and why.

In addition, several studies point to the importance of facilitators guiding the construction of sociomathematical norms (Campbell & Elliott, 2011; Elliott, et al., 2009; Kazemi, et al., 2007). The relevant sociomathematical norms concern the ways that mathematical work is interactively accomplished between teachers and a leader. For example, the kinds of mathematical ideas that teachers feel obligated to bring out in their explanations and the particular mathematical justifications pursued during these discussions constitute sociomathematical norms. Without this guidance from knowledgeable facilitators, conversations in professional development can lose their focus and fail to help teachers support their students' learning in classrooms (Borko et al., 2008; Cobb, Zhao, & Dean, 2009).

Conclusion. By engaging in the activity of doing mathematics, coaches can support the development of teachers' conceptions of what it means to do mathematics, as well as of their mathematical knowledge for teaching. In addition to doing mathematics together and discussing mathematical reasoning, coaches can step back and make explicit what they did to press for explanations, justifications, and connections among strategies. These types of discussions are likely to support teachers' in learning how to enact these practices in their own classrooms.

Analyzing Student Work

Research conducted over the past 20 years indicates that teachers' understanding of students' mathematical thinking is integral to effective instruction (Carpenter, Fennema, & Franke, 1996; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Jacobsen and Lehrer, 2000; Schifter, 1998; Villasenor & Keptner, 1993). Examining

student work has been proposed as a primary activity for learning about student thinking (Carpenter, Fennema, & Franke, 1996; Cobb, Zhao, & Dean, 2009; Franke, Kazemi, Shih, Biagetti, & Battey, 2005; Jacobson & Lehrer, 2000; Little, Gearhart, Curry & Kafka, 2003; Schifter, Bastable, & Russell, 1997; Schifter & Fosnot, 1993). Many current research efforts are premised on the assumption that by observing and describing student solutions, teachers will develop an understanding of students' diverse ways of reasoning, and that these understandings can inform their instructional practices (Zhao, 2011). However, simply bringing together teachers to look at student work does not necessarily open up opportunities for learning. Instead, the ways student work is used, the ways classrooms are represented in teacher talk, and the norms and habits of professional discourse influence the potential impact on teacher learning and knowledge (Crespo & Featherstone, 2006; Crockett, 2002; Little, 2004; Little et al., 2003).

There are many commercially-published professional development programs that include samples of student work (see for example Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Dolk, Fosnot, Cameron, Teig, & Hersch, 2005; Schifter, Bastable, & Russell, 1999; Schifter, 1998; Stein, Smith, Henningsen & Silver, 2000). However, the studies reviewed below primarily investigated teachers examining student work from their own classrooms. Using student work from teachers' own classrooms is promising for connecting the professional development activities to teachers' classroom practices and gives them opportunities to consider their own students' current understandings about particular big mathematical ideas.

The studies described in this section show that through collectively analyzing student work, teachers have opportunities to learn about student mathematical reasoning,

how students develop an understanding of significant mathematical ideas, and about how to elicit and build on students' mathematical thinking during instruction (Crockett, 2002; Kazemi & Hubbard, 2008). For the most part, the studies focused on shifts in teachers' discourse and evolving norms of the group as evidence of teachers' learning (Kazemi & Hubbard, 2008; Thompson, Braaten, Windschitl, Sjoberg, Jones, & Martinez, 2009; Windschitl, Thompson, Braaten, 2010). For example, Crockett (2002) conducted a year-long study examining a group of upper elementary mathematics teachers who worked together to plan for lessons, reflect on lessons taught, and assess student work products from those lessons. Crockett facilitated the sessions and relied on a protocol to support the teachers' examination of students' work. When teachers' examined student work, they were supported to challenge each other's assumptions about mathematics and justify what counts as mathematical understanding. Crockett argues that this led to the teachers to shift in diagnosing student thinking (and errors), and prompted them to reconsider their current instructional practices. Although Crockett did not examine teachers' instructional practices, she found evidence that teachers' shifted in the ways they talked, both while planning for upcoming instruction and while debriefing the implementation of a particular lesson by focusing on student thinking.

Studies in science education have examined how analyzing student work influenced the ways in which teachers framed the use of assessments in instruction. Windschitl and colleagues conducted a series of studies with high-school science teachers in which they met monthly to discuss improving their practice (Thompson, et al., 2009; Windschitl, Thompson, Braaten, 2010). Using protocols, the teachers engaged in a cycle of inquiry, reflection, and action that included collecting and analyzing samples of their

own students' written work. In addition to written work, many teachers found it useful to collect video samples as a way to share images of classroom practice (see also studies in mathematics education: Dolk, et al., 2005; Kazemi & Franke, 2004; Schifter, Bastable, & Russell, 1999). They found that teachers reorganized the ways in which they framed instruction and came to view student work as evidence of student understanding and as a resource for instructional improvement (see also Gearhart, Nagashima, Pfothenauer, Clark, Schwab, Vendlinski, Osmundson, Herman, & Bernbaum, 2006).

Franke and colleagues have conducted a series of studies to investigate how teachers are supported to learn about students' mathematical reasoning (Franke & Kazemi, 2001; Franke et al., 1998; Kazemi & Franke, 2004). Facilitated by the researchers, group of teachers at an elementary school met once a month throughout the school year in order to examine their students' mathematical work. Teachers were provided with common problems to use in their classrooms and were supported to make observations of their own students' mathematical thinking using principles and terminology from *Cognitively Guided Instruction* (see Carpenter, Fennema, Franke, Levi, & Empson, 1999; Fennema, Franke, Carpenter, & Carey, 1993). Teachers were also provided with ongoing, in classroom support by the facilitators. The researchers found that as a consequence of participating in this professional development, teachers began to attend to the details of children's thinking. As a result, during the collaborative meetings, teachers began to generate strategies for eliciting student thinking, and to develop possible trajectories for instruction and student learning. The authors indicated that this shift in beliefs would support teachers' development of instructional practices that focused on student thinking. With the additional support from the facilitators in their

classrooms, it is likely that teachers began to make shifts in their instructional practices as well; however, the authors did not measure changes in teachers' practices.

Additionally, researchers who have examined use of student work in other subject areas and at other grade levels reported similar findings (Curry, 2008; Gearhart, et al., 2006; Little, 2007; Thompson, et al., 2009). Teachers were also provided with opportunities to regularly examine student work with their colleagues. As a result, these studies indicate that as teachers used rubrics to analyze student work, they improved their instruction by selecting tasks that were both better aligned with goals for student learning and that built on students' current thinking (Gearhart et al., 2006). In addition, the participating teachers typically began to hypothesize about the relationship between their instructional moves and their students' reasoning (Little, 2007; Curry, 2008), and to consider the types of questions that they might ask to build on student thinking (Gearhart et al., 2006; Curry, 2008; Thompson et al., 2009). Evidence in these studies suggests that, as teachers examined the relationship between students' thinking, mathematical tasks, and instructional practices, they began to consider possible changes in the ways that they selected and enacted mathematics tasks in order to better support their students' mathematical learning.

Many of the studies that I have reviewed emphasize the importance of the facilitator in making the study of student work productive. Little and colleagues (2003) examined three professional development programs that used student work and identified a number of common practices that the facilitators used in order to shape the conversations. They reported that facilitators made decisions in advance about what the purpose of examining student work would be and which samples should be examined to

achieve these goals. Once selected, facilitators assisted teachers in sharing the background of the task, explaining how the task fit into a larger instructional sequence, and describe the context in which the students produced the work.

Facilitators then directed the conversations to focus on student thinking, which is important because most teachers' primary orientation to student work is to evaluate the correctness of their answers (Cobb, Zhao, & Dean, 2009; Crespo & Featherstone, 2006; Little et al., 2003; Thompson et al., 2009). For the activity to be productive, it is important that teachers move beyond an evaluative perspective and look for evidence of students' thinking. For example, Zhao (2011) found that teachers need to consider: what students did to solve the problem, why they chose to solve it in that way, and what their strategies reveal about their understanding of key mathematical ideas. To assist teachers in answering these questions, many professional development programs have developed protocols designed to organize discussions and structure participation (Little et al., 2003). These protocols orient teachers away from making evaluations and towards describing student reasoning. Facilitators helped teachers make productive use of the protocols and routinely pressed teachers to "describe the work without judging it", "interpret the work", or ask each other "clarifying questions" about the work (Little et al., 2003).

The role of facilitators also appears to be crucial in supporting teachers to generate questions they can ask during instruction to elicit students' thinking, give helpful feedback to students, and identify which strategies to choose to highlight in a whole class discussion (Gearhart et al., 2006; Kazemi & Franke, 2004; Kazemi & Hubbard, 2008; Thompson et al., 2009; Zhao, 2011). Considering interactions of this type between teachers and students supports teachers' development of ambitious

instructional practices. These discussions help hone teachers' abilities to seek additional information through probing students for more elaborate responses and analyzing them (Doerr, 2006; Schifter, 1998). Once teachers had the opportunity to experiment with these instructional practices, facilitators assisted teachers in making sense of what took place during the lesson. They supported teachers to understand how the strategies used by students reflected their current understandings and, in turn, how this might impact instructional decisions and future goals for students' learning (Kazemi & Franke, 2004; Little et al., 2003; Thompson et al., 2009).

Conclusion. By examining student work, mathematics coaches can support teachers' development of an understanding of students' reasoning and of instructional practices that incorporate students' thinking (Zhao, 2011). Franke and colleagues (1998) argue that, through this focus on student work, opportunities arise for teachers' classrooms to become environments for continued learning, which enables teachers to connect their knowledge of student's thinking to daily interactions with students. Mathematics coaches can further support teachers' understanding of student thinking by working with teachers in their classrooms. Similar to the support that Kazemi and Franke provided to teachers in their studies, coaches might model questions that elicit students' thinking and assist teachers in interpreting students' work and in deciding which solution strategies to highlight in the whole class discussion. In doing so, coaches would support teachers' development of ambitious instructional practices that respond directly to students' current mathematical reasoning.

Analyzing Classroom Video

The use of classroom video as a representation of practice has become increasingly common in professional development and teacher education in recent years (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Santagata, 2009; and Sherin, 2004; Zhang, Lundeberg, Koehler, & Eberhardt, 2011). Typically the intent of analyzing video recordings is to shift teachers' attention away from the exploration of vague perceptions about what transpired in a classroom (Ball & Cohen, 1999) and towards an evidence-based analysis of how classroom activities and interactions support students' learning (Borko et al., 2008; Rosean, Lundeberg, Cooper, Fritzen, & Terpstra, 2008). Professional development programs can provide teachers with opportunities to examine video from other teachers' classrooms (i.e., from teachers not participating in the program) or from their own classrooms (i.e., teachers participating in the program). Borko and colleagues (2008) argued that video from teachers' own classrooms situates their exploration of teaching and learning in a more familiar and potentially more motivating environment. The studies reported on in this section are primarily of teachers viewing video from their own or their colleagues' classrooms.

Sherin and colleagues have conducted a series of studies that examine a professional development model, called "Video Club," in which teachers watch and discuss excerpts of videos from their classrooms (Sherin & Han, 2004; Sherin, 2004; Sherin & van Es, 2005; van Es & Sherin, 2006; van Es & Sherin, 2008; Sherin & van Es, 2010). In this professional development model, fourth and fifth grade teachers in an urban school participated in a yearlong series of meetings of a video club that were facilitated by university mathematics educators. During the professional development

sessions, facilitators supported and pressed the teachers to examine student mathematical ideas and to use evidence from video segments and transcripts to support their claims about student understanding. Sherin and colleagues found that as a result of examining classroom video, teachers' analysis of their own instruction shifted from a focus on classroom management to student mathematical thinking (see also Rosean et al., 2008). There was evidence that after the teachers had analyzed video for an extended period, during the Video Club, they began to verbalize the importance of attending to student ideas during instruction and modified in their classroom practices in order to elicit students' thinking (Sherin & van Es, 2005; van Es & Sherin, 2008). Additionally, Sherin and van Es (2010) documented changes to teachers' instructional practices, which included providing extended opportunities for student thinking, eliciting multiple strategies from students, and probing students' underlying understandings.

In a similar series of analyses, Borko and colleagues examined how classroom video can be used as a tool for supporting teacher learning (Borko, 2004; Borko, et al., 2005; Borko, et al., 2010; Clark & Borko, 2004; Jacobs, Hollingsworth, & Givvin, 2007; Koellner, Schneider, Roberts, Jacobs, & Borko 2008). The researchers examined a professional development model for middle grades mathematics teachers that included a component of analyzing classroom video. They found that over time teachers' full-group conversations around video became more focused, in-depth, and analytical about specific issues related to teaching and learning. Borko and colleagues documented that in analyzing episodes of their colleagues' instruction, teachers came to appreciate their students' capacity for mathematical reasoning and, as a consequence, learned new pedagogical strategies. Although researchers did not quantify change in teachers'

practices, they found that viewing episodes from their own classrooms allowed teachers to examine their attempts at enacting new pedagogical strategies, and to identify areas for improvement.

Although the findings from Sherin's and Borko's work are encouraging, it is also clear that teachers do not necessarily gain new insights about their practice from simply watching classroom video (Brophy, 2004). The importance of the facilitator's role in pressing and supporting teachers has been identified in several studies. These studies indicate that in order for analyzing video to be a productive activity, the facilitator must establish a clear purpose for viewing the video that is based on specific goals for teachers' learning (Borko et al., 2008; Brophy, 2004). For example, Borko and colleagues found that facilitators were able to identify potentially productive goals when they were pressed to consider questions such as: What focus would capture the teachers' attention and stimulate discussion? What video clips would help make particular points, without causing stifling discomfort for the group members or disempowering them as professionals? How should multiple clips from a variety of lessons be sequenced to best provide opportunities for learning? (Borko et al., 2008). By answering these questions, facilitators are better prepared to support teachers' learning.

As teachers prepare to view a classroom episode, an important part of facilitators' work is to support them to understand key contextual features of the video (Zhang et al., 2011). To do so, facilitators support teachers in sharing information about the clip, such as: (a) the instructional goals and mathematical tasks for the lesson, (b) student characteristics, and (c) what happened before and after the videotaped lesson. The study by Borko and colleagues (2008) reveals that effective facilitators posed structured

discussion questions and routinely pressed the group to take a more critical look at students' thinking and the teachers' role (e.g., "How did the teacher's questions help him to understand how Kaitlin derived her expression? What additional questions would you ask [Kaitlin] to further understand her mathematical thinking?" Borko et al., 2008, p. 428). Such questions were found to assist groups of teachers to develop explanations for students' contributions that had not been clear to the teacher during instruction (Sherin & Han, 2004); discuss possible reasons behind various decisions made by the teacher on the video (Sherin, 2004); and consider alternative strategies that the teacher might have used, including considering better ways of asking questions to uncover student thinking (Borko et al., 2008).

Conclusion. While taking teachers' current practices into consideration, mathematics coaches can carefully select video clips to analyze with teachers. Through viewing video together, teachers can analyze instructional practices and be supported to engage in conversations about the role of the teacher in supporting the development of students' reasoning. Through these discussions, teachers can develop more sophisticated understandings of ambitious instructional practices and begin to implement them.

Rehearsing High Leverage Practices

Recent research distinguishes between two important types of activities that contribute to effective professional learning: pedagogies of investigation and pedagogies of enactment (Grossman, Hammerness, & McDonald, 2009; Grossman & McDonald, 2008). In previous sections, I examined several pedagogies of investigation, including analyzing video of classroom instruction and examining student work. Pedagogies of

enactment involve planning for, rehearsing, and enacting high-leverage practices in a graduated sequence of increasingly complex settings. Grossman and colleagues (2009) argue that pedagogies of enactment should be added to the existing repertoire of pedagogies of reflection and investigation.

Enactment refers to simulations of instructional practice that are designed to enable collective analysis of practice (Grossman, et al., 2009). In this section, I focus on the activity of rehearsing in which teachers act out hypothetical classroom interactions in front of their colleagues in order to receive feedback (Horn, 2010; Horn, 2005; Kazemi, Franke, Lampert, 2009; Lampert & Graziani, 2009; Lampert, 2010; Lampert, et al., 2010). Through *rehearsals*, teachers are supported to elaborate, reconsider, and revise their understanding of complex teaching situations (Horn, 2010). I draw on the professional education and teacher learning literature to examine how rehearsals can support teachers' development of ambitious instructional practices.

Grossman and colleagues have conducted a series of studies in which they investigated how people learn professional practice by analyzing the induction practices in several professions, including clergy, clinical psychologists, and teachers (Grossman, et al., 2009; Grossman, Hammerness, & McDonald, 2009; Grossman & McDonald, 2008). Their findings indicate that these programs broke down the profession's core practices into discrete routines that novices must learn. For example, they noted that medical students encounter simulated patient experiences in the course of their training. As medical students learn to conduct a physical exam and take histories, they have the opportunity to practice these routines with a trained actor who simulates certain illness patterns for novices. This allows medical students to begin to hone their practices before

entering the more authentic, but also more complex, setting of the hospital. Similar to the simulated patient experience for medical students, Grossman and colleagues argue that teachers need experiences that support their development of core practices and routines. Therefore, teacher education should move away from a curriculum focused on what teachers need to know, to a curriculum organized around core practices in which knowledge, skill, and professional identity are developed in an integrated manner (Grossman & McDonald, 2008).

Building on the work of Grossman and her colleagues, a number of researchers are currently attempting to identify “high-leverage practices” that might be targeted in teacher education and professional development (e.g., Franke, Grossman, Richert, & Schultz, 2006; Kazemi & Hintz, 2008; Kazemi, Lampert, & Ghousseni, 2007 as cited in Grossman, Hammerness, & McDonald, 2009). Although definitions of what constitutes high leverage practices vary across researchers, all definitions have the following characteristics: occur with high frequency in teaching, allow teachers to learn more about students and teaching, preserve the integrity and complexity of teaching, and have the potential to improve student achievement. In mathematics, the following practices have been identified as high leverage: leading a whole class discussion (Franke, Carpenter, Levi, & Fennema, 2001); representing concepts with examples (Franke et al., 2001); supporting students to share strategies (Kazemi, Franke, & Lampert, 2009); posing a string of related math computation problems to students (Kazemi, Franke, & Lampert, 2009; Fosnot & Dolk, 2001); and setting up complex tasks (Jackson, Garrison, Wilson, Gibbons, Shahan, 2011). Rehearsing these practices gives teachers opportunities to develop a repertoire of instructional routines (Lampert, 2010).

The studies I have discussed thus far focus on teachers' initial professional education. It is also important to look at literature that examines how practicing teachers' learning can be supported by rehearsals. Horn and Little observed and analyzed practicing teachers' collaborative conversations in order to understand how these productive conversations provide resources for teachers learning (Horn, 2005, 2007; Horn, 2010; Horn & Little, 2010; Little, 2002, 2003; Little & Horn, 2007). Horn identified one form of discourse, teaching rehearsals, which were important sites for representing teaching practice. These discourse structures "focus teachers on the specificity of the classroom and, when coupled with the re-visioning participation framework (Goffman, 1981), help them develop knowledge for teaching that is at once rooted in general principles and deeply situated in practice" (Horn, 2010, p. 227-228). Horn argued that teaching rehearsals allowed teachers to model lessons with colleagues who had knowledge of the school, student, and teaching contexts. Horn did not examine changes in the participating teachers' instructional practices, but suggests that these conversations might have influenced how instruction played out in their classrooms.

It is important to understand the role of the facilitator in leading rehearsals and establishing norms for the activity. Kazemi and colleagues argue that if rehearsals are to be productive, it is important for the facilitator to establish how the other teachers should behave as students (e.g., being uncooperative) and whether they should pose solutions that are correct or incorrect (e.g., common misconceptions) (Kazemi, Franke, & Lampert, 2009). To make decisions about this and other norms, the facilitator should set goals for teachers' learning that are based on an assessment of teachers' current understandings and practices. The facilitator's role includes asking questions and producing assertions

that reflect errors that students often make (Kazemi, Franke, & Lampert, 2009).

Interjections of this type can support teachers in making sense of and responding to students, and in enacting routines less complex than the classroom.

Research also highlights that frequent breaks in the discussion are important for critique and questioning about the comments “students” made, and suggestions for further eliciting student thinking (Grossman, Hammerness, & McDonald, 2009; Horn, 2005; Kazemi, Franke, & Lampert, 2009). During these discussions, teachers can raise questions about situations that they have experienced in their own classrooms. In addition to pausing the enactment to give a suggestion, the facilitator can ask the teacher to go back and practice asking a question again. Furthermore, facilitators provide feedback about the enactment of specific routines, such as revoicing of mathematical ideas (Chapin, O’Conner, & Anderson, 2003; Grossman, Hammerness, & McDonald, 2009), thereby helping teachers develop a shared understanding of ambitious practices (Horn, 2010; Kazemi, Franke, & Lampert, 2009).

Grossman and colleagues addressed the issue of how rehearsals might fit into a larger system of teacher supports and suggest how this work can be structured: (a) teachers collaboratively prepare to teach a mathematics lesson by examining mathematics tasks and generating possible student responses, (b) rehearse the lesson with one another and identify potential trouble spots, (c) enact the lesson in their own classrooms with their students while the facilitator observes, and (d) engage in a post-lesson discussion with the facilitator about how to refine both the lesson and the enactment of particular practices. Through this cycle of co-planning and enacting in less complicated settings

prior to implementing the lesson in the classroom, teachers have opportunities to learn and develop complex instructional practices with the assistance of their colleagues.

Conclusion. Rehearsing is useful as a professional development activity because the refinement of skilled practice requires multiple opportunities to try out new routines and receive specific feedback about what is and is not working well (Ericsson, 2002; Schon, 1987). By focusing on a core set of high leverage practices, mathematics coaches can address teaching as a complex task while making the learning demands manageable for teachers (Grossman, Hammerness, & McDonald, 2009). For example, many teachers struggle to master the complex practice of leading a whole classroom discussion. Through rehearsals, coaches can support teachers in developing instructional routines that are central to the practice of leading discussions, including identifying generative questions and choosing rich problems to discuss, as well as learning to re-voice student ideas in the course of a discussion.

Examining Activities Conducted One-on-One with Teachers in Their Classrooms

The activities I have discussed thus far involve coaches working with groups of teachers. Many of the studies I examined also included the provision of additional support for teachers in their classrooms (Carpenter, Fennema, & Franke, 1996; Franke, et al., 1998; Schifter, Bastable, & Russell, 1999; Schifter, 1998; Schifter & Fosnot, 1993; Villasenor & Keptner, 1993). As stated previously, ongoing follow-up support is a characteristic of effective professional learning (Ball, 1996; Garet, et al., 2001; Guskey, 2000; Putnam & Borko, 2000; Spillane, Reiser, & Gomez, 2006). One-on-one activities mentioned in research on content-focused coaching include: (a) co-teaching, (b)

modeling, (c) observing and debriefing challenges of implementation. The coaching literature typically does not justify these activities in terms of the types of learning opportunities that might arise for teachers; therefore, in this section I draw on the professional learning and teacher education literature to assess whether each activity is potentially productive for supporting teachers' development of ambitious practices.

Co-teaching

Researchers who have examined how people learn to participate in various complex communities of practice have emphasized the importance of co-participating in a practice with a more knowledgeable other (Bourdieu, 1992; Brown, Collins, & Duguid, 1989; Brown, Stein, & Forman, 1996; Lave & Wenger, 1991; Roth & McRobbie, 1999). Bourdieu (1992) asserts that there is no other way of mastering the fundamental principles of practice than by practicing it alongside a more experienced other who applies precepts and provides assurance, reassurance, and corrective feedback. Tharp and Gallimore (1988) argue that co-participation supports the learner in ways that language alone cannot do: “the development of common understanding of purposes and meanings of the activity, [and] the joint engagement in cognitive strategies and problem solving are all aspects of interaction that influence each participant” (p. 89). Similarly, Tobin and colleagues explain that, “what is salient in this learning situation is that knowledge of teaching, as it is enacted, is adapted in situ—as distinct from the reconstructed knowledge that is adapted during reflective analyses that occur after teaching has occurred” (Tobin, Seiler, & Smith, 1999; p. 72). Through co-participation, the more knowledgeable other is able work alongside the novice in authentic situations, where both see the classroom from

similar vantage points, share experiences and generate understanding of these experiences (Roth & McRobbie, 1999; Tobin, Seiler, & Smith, 1999).

While co-teaching is included in some of the professional development designs that I examined in prior sections, very few studies investigated the conditions under which co-teaching is productive as a means of supporting to K-12 teachers' learning. However, a number of studies have focused specifically on co-teaching as a support for teachers' learning in either teacher education or teacher induction³ (Eick & Dias, 2005; Eick, Ware, & Williams, 2003; Milne, Scantlebury, Blonstein, & Gleason, 2011; Roth, 1998a, 1998b; Roth & McRobbie, 1999; Roth, Masciotra, & Boyd, 1999; Roth & Tobin, 2001, 2002; Roth, Tobin, Carambo, & Dalland, 2004; Scantlebury, Gallo-Fox, & Wassell, 2008; Tobin & Roth, 2006). Most of this research draws on Roth and Tobin's definition of co-teaching as classroom teaching experiences that "are coordinated with meetings during which co-teachers and [novice teachers] debrief, make sense of the events, evaluate what has happened, critically reflect on their understanding, and construct local theory and new action possibilities" (Roth & Tobin, 2001, p. 18). In most of these designs, novice teachers co-teach for a certain length of time with an assigned mentor teacher. In one study, Roth and colleagues found evidence that as a result of co-teaching, a novice teacher's competence in asking students questions improved over time (Roth, Masciotra, & Boyd, 1999). Though they did not document the process by which the novice teacher learned, they attributed much of novice teacher's rapid development to the fact that she was co-teaching with a more experienced other and engaging in conversations about instruction and learning.

³ For each teacher education study cited, I used the authors' original terminology to refer to the new teacher (e.g., 'novice teacher' or 'student teacher') and supporting teacher (e.g., 'mentor teacher' or 'cooperating teacher').

Eick and colleagues built on this initial work and examined how co-teaching with experienced teachers influenced aspects of the domain-specific knowledge of secondary science student teachers over an eight-week period (Eick & Dias, 2005; Eick, Williams, & Ware, 2003). Student teachers were paired with mentor teachers for two consecutive periods of the same subject. During the first period, student teachers observed and assisted the mentor teacher by helping with materials and by working with small groups or individual students. Throughout the second period, the student teachers taught the same lesson with the mentor teachers providing assistance if the student teacher needed help explaining difficult concepts or with student behavior. After engaging in co-teaching with their mentor teacher, most of the student teachers reported feeling supported in their attempts to take the lead in teaching. Some of them reported trying change their own practices by imitating what they perceived as their mentor teachers' strengths. For example, one student teacher reported that she tried to implement ongoing questioning techniques that she believed had engaged students in understanding the material. Eick and colleagues argued that by engaging in this activity, student teachers had the opportunity to see ways of supporting students' learning through inquiry, which improved their confidence in teaching in ambitious ways. Their observations provided evidence that student teachers learned how manage students and to interact with them. In addition, they found that there was an increased focus on the effectiveness of the instruction and implications for students' learning when the student teachers and their mentors debriefed after lessons.

In order to better understand the role of the facilitator in co-teaching, I examined Eick and colleagues' (2003) analysis of how mentors assisted teachers in the activity.

They found that the mentors' assistance included logistical support, such as assisting with the collection, dissemination, and setting up of materials needed for the lesson. In addition, mentors provided ongoing verbal assistance and interjected throughout the entire lesson, both to address student behavior issues (e.g., helping to manage the transition between separate laboratory portions of the lesson) and to provide clarification or questioning for student understanding (e.g., asking students questions particular to the lesson to help assess student understanding). If novice teachers struggled to answer a student's question or experienced difficulties with classroom management, mentor teachers typically made on-the-spot interventions in real time. Eick and colleagues argued that student teachers had opportunities to learn from these interventions as well as from the additional in-depth verbal and written feedback provided by the mentors after the lesson.

Conclusion. Co-teaching provides a starting point for conversations about practice and discussions about specific events between a novice and a more knowledgeable other (Tobin, Seiler, & Smith, 1999). Coaches can support teachers both during instruction by providing ongoing assistance, and after instruction by supporting teachers in analyzing specific aspects of the lesson. For example, coaches can assist teachers in uncovering students' thinking by suggesting questions to ask students (e.g., why you decided to represent the problem in this way?), and by demonstrating questions intended to help students make sense of a specific strategies (e.g., can anyone explain it in their own word?). Crucially, coaches and teachers can later ground their conversations in the experience of co-teaching in *this* classroom, with *these* students (Tobin & Roth, 2006). Together, they can seek to understand what happened during the lesson, discuss

what should take place in subsequent lessons, and discuss possibilities for improving teaching and learning.

Modeling

While co-participating is an important support, observing a more knowledgeable other engage in the practice can also be productive. Modeling by a more expert other might be useful at specific points in teachers' development, notably when they are beginning to consider how to enact a particular instructional practice, and when they need assistance in developing an image of accomplished enactment of that practice (Feiman-Nemser, 2001; West & Staub, 2003). Modeling can be a starting point for a longer process during which teachers develop and refine new instructional practices.

Some studies have investigated conditions under which modeling is a productive way to support beginning K-12 teachers (Achinstein & Barrett, 2004; Feiman-Nemser, 2001). Feiman-Nemser (2001) conducted a study to examine how one teacher's mentoring practices—including the activity of modeling—supported the work of beginning elementary teachers in an induction program. Feiman-Nemser conducted interviews with the beginning teachers and the mentor teacher, and observed beginning teachers' practices in order to understand the mentor's practices. The mentor described the activity of modeling as a way to give a "living example" of teaching. Through modeling, he hoped that novices would not only pick up on particular teaching ideas, but also begin to identify characteristics of good teaching. To accomplish this, he often stopped to highlight key aspects of teaching, and to explain to beginning teachers what he

was doing and why. After the lesson, the facilitator asked the beginning teachers to interpret what they saw.

Conclusion. There is little reason to believe that the activity of modeling will be sufficient by itself to support teachers' development of focal instructional practices. In order to provide teachers a coherent set of supports, coaches need to consider whether teachers would benefit from modeling. Therefore, it is important that coaches identify a goal for modeling and support teachers to analyze what they saw, highlighting specific instructional practices and instances in which the coach made decisions based on students' reasoning.

Observing and Debriefing

Some learning theorists have described learning as a process of moving from assisted performance to unassisted performance (Brown, Stein, & Forman, 1996; Lave & Wenger, 1991; Rogoff, 1990; Tharp & Gallimore, 1988; Vygotsky, 1978). Researchers who examine content-focused coaching have suggested that coaches' one-on-one assistance in classrooms could include modeling as a first step, followed by co-teaching and finally, observing the teacher in action and providing feedback (L'Allier, Elish-Piper, & Bean, 2010; West & Staub, 2003). In this proposal, the activity of observing comes after the teacher has had time to practice and work more closely with the coach.

Literature on professional development and teacher education has highlighted the importance of teachers receiving feedback on their instructional practices from a more knowledgeable other (Barrett, Jones, Mooney, Thornton, Cady, Guinee, & Olson, 2002; Darling-Hammond, 2006; Garet et al., 2001; Grossman, Hammerness, & McDonald,

2009; Horn, 2005; Lampert, et al., 2010; Putnam & Borko, 2000; Sherin & Han, 2004).

I examine this literature in order to consider what novices have the opportunity to learn from engaging in discussions after attempting to implement specific instructional practices. Researchers of teacher education have described generally that post-observation dialogues should include discussing the issues that impact teaching and learning, and collectively generate solutions to problems of teaching or learning (Roth & Tobin, 2001, 2005; Scantlebury, Gallo-Fox, & Wassell, 2008; Tobin, 2006), but the details of this process is vague.

While other studies have examined the provision of feedback in general, I was able to locate only one teacher education study that has examined the types of feedback that support the development of high quality practices (Borko & Mayfield, 1995). Borko and colleagues conducted a series of studies to examine the nature of student teachers' and mentor teachers' relationships (Borko & Mayfield, 1995; Borko, Eisenhart, Brown, Underhill, Jones, & Agard, 1992; Eisenhart, Borko, Underhill, Brown, Jones, & Agard, 1993). Borko argued that feedback from a more knowledgeable other is a promising support: "at their best...cooperating teachers and university supervisors can provide feedback about specific lesson components, suggestions about new ways to think about teaching and learning, and encouragement to reflect on one's practice" (Borko & Mayfield, 1995, p. 15). They examined four middle grades mathematics student teachers' experiences in their school placements in order to understand the characteristics of teaching conferences between student teachers and their university supervisors and mentor teachers. They found that the discussions between the student teachers and university supervisors or mentor teachers were generally brief and superficial. The

debriefing conversations did not focus on the nature of mathematics or on strategies for teaching particular mathematical ideas. The potential for feedback about specific lesson components and suggestions about new ways to think about teaching and learning was not realized with the participating university supervisors or mentor teachers in this study.

Conclusion. The Borko and Mayfield (1995) study indicates that more work is needed to uncover the types of feedback that are likely to support teachers' development of ambitious practices. However, the study acknowledges the importance of providing feedback to teachers after observations. It seems reasonable for coaches to provide feedback that is centered around aspects of instruction, such as the implementation of cognitively demanding tasks or the selection of which student solution strategies to present in a whole class discussion (Hiebert et al., 1997; Jackson, Shahan, Gibbons, & Cobb, in press; Smith, Bill, & Hughes, 2008).

The Coaching Cycle

Although the coaching cycle is not identified as one of the seven activities, it is important to examine because it is frequently highlighted in the content-focused coaching literature (Hayes, 2010; May, 2010; Teemant, Tyra, & Wink, 2009; Bradley, 2007; Neufeld & Roper, 2003; Olson & Barrett, 2004; Poglinco et al., 2003). However, I was unable to pinpoint research that has examined how the coaching cycle supports teachers' development. Typically, a cycle consists of three stages: a pre-observation (planning) conference, an observation of the implementation of a lesson, and a post-observation (debriefing) conference. During the pre-observation phase, a coach typically co-plans with a teacher. The coach can press the teacher to think through components of the

lesson (e.g., by asking about their mathematical goals for the lesson). Smith and colleagues have created a protocol that is designed to support teachers' in planning lessons around cognitively demanding mathematics tasks (*Thinking Through the Lesson Protocol*: Smith, Bill, & Hughes, 2008). Coaches and teachers can use similar tools to help anticipate what students might do and to generate questions that will promote student learning. During the pre-observation conference coaches and teachers can also discuss specific instructional practices that coaches can look for as they observe the implementation of the lesson (e.g., how the teacher helped students make connections between solution strategies during the whole class discussion).

The second phase in the cycle is the actual instructional observation. If coaches are merely observing, then they can take notes using the pre-conference discussion as framework for structuring feedback. Depending on the learning goals for teachers, coaches can take a more active role during this time as well. After the lesson, there is a post-observation in which teachers and coaches meet to debrief. During this discussion, coaches can provide feedback based on the lesson in light of the questions posed during the pre-observation conference. In addition, coaches can help teachers set future goals for developing their instructional practices. Although this activity appears likely to support teachers' development if it is implemented successfully, it is often difficult for coaches to schedule all three components. Furthermore, when considering the other activities in which coaches can engage teachers, it seems most efficient to co-plan for instruction with groups of teachers rather than with individual teachers. By doing so, coaches can then observe teachers' implementation of those lessons and provide them with individual feedback that is specific to their instructional practices.

Summary

The one-on-one activities I have discussed aim to support teachers' analysis of practice through dialogue that is grounded shared teaching experiences (Eick, Ware, & Williams, 2003). In each activity, coaches should develop a plan for working with an individual teacher that is both deliberate and flexible. (L'Allier, Elish-Piper, & Bean, 2010). For example, it is important that coaches model instruction for teachers with a clear purpose in mind, based on their assessments of teachers' current instructional practices. In addition, many of the studies described above highlight the importance of coaches engaging in discussions with teachers after they have observed the teachers' instructional practices. The purpose of these discussions is to help teachers debrief their attempts to implement various instructional practices, talk with a more knowledgeable other about how the lesson unfolded, and negotiate an agenda for continued improvement. When coaches intentionally make links between what is being learned across the various professional learning settings (including district- and school-based professional development), they contribute to a coherent set of opportunities for teachers' development (Cobb & Jackson, 2011; Darling-Hammond et al., 2009; Garet et al., 2001),

Discussion

This conceptual analysis identified activities in which studies have shown that teachers have been supported to develop ambitious instructional practices, in order to identify a set of activities that are potentially productive in which coaches and teachers can engage. Potentially productive activities that coaches might conduct with groups of teachers include: (a) doing mathematics, (b) examining student work, (c) analyzing

classroom video, and (d) rehearsing aspects of practice. Potentially productive activities that coaches might conduct with individual teachers include: (e) co-teaching, (f) modeling, and (g) observing instruction and debriefing challenges of implementation. As I have attempted to illustrate, there is some evidence that these types of activities can give rise to substantial learning opportunities for teachers. Further work is needed to understand whether and under what conditions these activities, when facilitated effectively by coaches, support teachers' development of high quality instructional practices.

Additionally, it is important to understand the capabilities that coaches need to develop to both make productive decisions about types of activities, and to successfully implement activities. The findings of several studies indicate that the development of relatively accomplished instructional practices is a necessary, but not sufficient, for developing effective coaching practices (Borko, et al., 2008; Elliott, et al., 2009). Further work needs to be done to delineate what facilitators and coaches should do to support teachers' learning as they engage in these various activities. For example, it is important to identify questions that coaches can pose routinely in each activity to press teachers on key issues (e.g., anticipating student solutions to particular tasks or identifying the key mathematical ideas in a task). These questions are likely to influence the nature of interactions and thus the extent to which teachers are supported to develop ambitious practices (Coburn & Russell, 2008).

In addition to identifying what coaches need to know and be able to do, it is also important to investigate how to support coaches in developing these capabilities. The findings of a recent study show that coach professional development can influence the

types of conversations in which coaches engage teachers (Coburn & Russell, 2008). Similar to teachers, coaches' learning needs to be scaffolded by co-participating in learning opportunities central to coaching with more accomplished other, typically district leaders of mathematics.

In this analysis, I examined research on professional learning that has shown some evidence that the activities could be potentially productive in providing opportunities for teachers to learn and develop ambitious instructional practices. Given the limited research base, these activities appear to be a reasonable way to proceed. While further work is needed to understand the types of expertise, supports, and conditions needed to assist coaches in developing these practices, currently we can rely on the teacher learning and professional development literature explained here to guide coaches in engaging in these types of activities with teachers in order to improve the quality of mathematics teaching at scale.

References

- Achinstein, B., & Barrett, A. (2004). (Re)Framing class- room contexts: How new teachers and mentors view diverse learners and challenges of practice. *Teachers College Record, 106*(4), 716-746.
- Ball, D. L. (1993). Halves, pieces, and twoths: Constructing representational contexts in teaching fractions. In T. P. Carpenter, E. Fennema & T. A. Romberg (Eds.), *Rational numbers: An integration of research* (pp. 157-196). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Ball, D. L. (1996). Connecting mathematics as part of learning to teach. In D. Shifter (Ed.), *What's happening in math class: Reconstructing professional identities* (Vol. 2, pp. 36-45). New York: Teachers College Press.
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389-407.
- Ball, D. L., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *Elementary School Journal, 109*(5), 458-474.
- Barrett, J., Jones, G., Mooney, E., Thornton, C., Cady, J., Guinee, P., & Olson, J. C. (2002). Working with novice teachers: Challenges for professional development. *Mathematics Teacher Education and Development, 4*, 15-17.
- Boaler, J., & Staples, M. (2008). Creating mathematical futures through an equitable teaching approach: The case of RAILSIDE SCHOOL. *Teachers College Record, 110*, 608-645.
- Bourdieu, P. (1992). The practice of reflexive sociology (The Paris workshop). In P. Bourdieu & L. J. D. Wacquant, *An invitation to reflexive sociology* (pp. 216-260). Chicago, IL: The University of Chicago Press.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15.
- Borko, H., Eisenhart, M., Brown, C. A., Underhill, R. G., Jones, D., & Agard, P. C. (1992). Learning to teach hard mathematics: Do novice teachers and their instructors give up too easily? *Journal for Research in Mathematics Education, 23*, 194-222.
- Borko, H., & Mayfield, V. (1995). The roles of the cooperating teacher and university supervisor in learning to teach. *Teaching and Teacher Education, 11*, 501-518.

- Borko, H., Frykholm, J. A., Pittman, M. E., Eiteljorg, E., Nelson, M., Jacobs, J. K., et al. (2005). Preparing teachers to foster algebraic thinking. *Zentralblatt für didaktik der mathematik: International reviews on mathematical education*, 37(1), 43–52.
- Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24, 417-436.
- Borko, H., Koellner, K., & Jacobs, J. (2011). Meeting the challenges of scale: The importance of preparing professional development leaders. Teachers College Record, Date Published: March 04, 2011. Retrieved from <http://www.tcrecprd.org> ID Number: 16358.
- Bradley, J. A. T. (2007). *Exploring an alignment focused coaching model of mathematics professional development: content of coach/teacher talk during planning and analyzing lessons*. University of Texas at Austin, Austin, TX.
- Brophy, J. (Ed.) (2004). *Advances in research on teaching: Vol. 10. Using video in teacher education*. Oxford, UK: Elsevier.
- Brown, C., Stein, M., & Forman, E. (1996). Assisting teachers and students to reform the mathematics classroom. *Educational Studies in Mathematics*, 31, 63–93.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-34.
- Campbell, M., & Elliott, R. (2011). An analytic frame for examining teachers' collaborative mathematics work to develop specialized content knowledge. Paper presented at the annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Reno, NV
- Campbell, P. D., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal* 111(3), 430-454.
- Cantrell, S. C., & Hughes, H. K. (2008). Teacher efficacy and content literacy implementation: An exploration of the effects of extended professional development with coaching. *Journal of Literacy Research*, 40, 95-127.
- Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loeff, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*, 26(4), 499-531.

- Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively guided instruction: A knowledge base for reform in primary mathematics instruction. *The Elementary School Journal*, 97(1), 3-20.
- Carpenter, T. P., Fennema, E., Franke, M., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction*. Portsmouth, NH: Heinemann.
- Chapin, S., O'Connor, C., & Anderson, N. (2009). *Classroom Discussions: Using math talk to help students learn*. Sausalito, CA: Math Solutions.
- Clark, K., & Borko, H. (2004). Establishing a professional learning community among middle school mathematics teachers. In M. J. Hoines and A. Fuglestad (Eds.), *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education (Vol. 2, pp. 223–230)*. Bergen, Norway: Bergen University College.
- Cobb, P., Zhao, Q., & Dean, C. (2009). Conducting design experiments to support teachers' learning: A reflection from the field. *Journal of the Learning Sciences*, 18, 165-199.
- Cobb, P., & Jackson, K. (in press-b). Towards an empirically grounded theory of action for improving the quality of mathematics teaching at scale. *Mathematics Teacher Education and Development*.
- Coburn, C. E., & Russell, J. L. (2008). District Policy and Teachers' Social Networks. *Educational Evaluation and Policy Analysis*, 30(3), 203-235.
- Cohen, D. K., & Ball, D. L. (1990). Policy and practice: An overview. In D. K. Cohen, P. L. Peterson, S. Wilson, D. L. Ball, R. Putnam, R. Prawat, R. Heaton, J. Remillard & N. Wiemers (Eds.), *Effects of state-level reform of elementary school mathematics curriculum on classroom practice*. East Lansing, MI: The National Center for Research on teacher Education and The Center for the Learning and Teaching of Elementary Subjects, College of Education, Michigan State University.
- Cohen, D.K., & Hill, H.C. (2001). *Learning policy: When state education reform works*. New Haven, CT: Yale University Press.
- Collins, A., Brown, J.S., & Newman, S. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*. Hillsdale, NJ: Erlbaum.
- Crespo, S. & Featherstone, H. (2006). Teacher learning in mathematics teacher groups: One math problem at a time. *AMTE Monograph: The Work of Mathematics Teacher Educators (3)*, 97-115.

- Crockett, M. D. (2002). Inquiry as professional development: creating dilemmas through teachers' work. *Teaching and Teacher Education*, 18, 609-624.
- Curry, M. (2008). Critical friends groups: The possibilities and limitations embedded in teacher professional communities aimed at instructional improvement and school reform. *Teacher College Record*, 110(4), 733-774.
- Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*, 86, 173-184.
- Darling-Hammond, L. (2006). Assessing teacher education - The usefulness of multiple measures for assessing program outcomes. *Journal of Teacher Education*, 57, 120- 138.
- Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Palo Alto, CA: Stanford University and National Council of Staff Development.
- Desimone, L., Porter, A., Garet, M., Yoon, K., & Birman, B. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Education Evaluation and Policy Analysis*, 24(2), 81-112.
- Doerr, H. M. (2006). Examining the tasks of teaching when using students' mathematical thinking. *Educational Studies in Mathematics*, 62(1), 3- 24.
- Eick, C., & Dias, M. (2005). Building the authority of experience in communities of practice: The development of pre-service teachers' practical knowledge through co-teaching in inquiry classrooms. *Science Teacher Education*, 89, 470-491.
- Eick, C., Ware, F., & Williams, P. (2003). Coteaching in a science methods course: A situated learning model of becoming a teacher. *Journal of Teacher Education*, 54, 74-85.
- Eisenhart, M., Borko, H., Underhill, R. G., Brown, C. A., Jones, D., & Agard, P. C. (1993). Conceptual knowledge falls through the cracks: Complexities of learning to teach mathematics for understanding. *Journal for Research in Mathematics Education*, 24, 8-40.
- Elliott, R., Kazemi, E., Lesseig, K., Mumme, J., Carroll, C., & Kelley-Petersen, M. (2009). Conceptualizing the work of leading mathematical tasks in professional development. *Journal of Teacher Education*, 60, 364-379.

- Ericsson, K. A. (2002). Attaining excellence through deliberate practice: Insights from the study of expert performance. In M. Ferrari (Ed.), *The Pursuit of Excellence in Education* (pp. 21-55). Hillsdale, NJ: Erlbaum.
- Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record*, 103(6), 1013-1055.
- Fennema, E., Franke, M. L., Carpenter, T. P., & Carey, D. A. (1993). Using children's mathematics knowledge in instruction. *American Educational Research Journal*, 30, 555-583.
- Fosnot, C. T. & Dolk, M. (2001). *Young Mathematicians at Work: Constructing Number Sense, Addition, and Subtraction*. Westport, CT: Heinemann.
- Frank, K. A., Zhao, Y., & Borman, K. (2004). Social capital and the diffusion of innovations within organizations: The case of computer technology in schools. *Sociology of Education*, 77, 148-171.
- Franke, M. L., Carpenter, T., Fennema, E., Ansell, E., & Behrend, J. (1998). Understanding teachers' self-sustaining, generative change in the context of professional development. *Teaching and Teacher Education*, 14(1), 67-80.
- Franke, M. L., Carpenter, T. P., Levi, L., & Fennema, E. (2001). Capturing teachers' generative change: A follow-up study of professional development in mathematics. *American Educational Research Journal*, 38, 653-689.
- Franke, M. L., & Kazemi, E. (2001). Teaching as learning within a community of practice: Characterizing generative growth. In T. Wood, B. Nelson, & J. Warfield (Eds.), *Beyond classical pedagogy in elementary mathematics: The nature of facilitative teaching* (pp. 47-74). Mahwah, NJ: Lawrence Erlbaum.
- Franke, M. L., Kazemi, E., Shih, J., Biagetti, S., & Battey, D. (2005). Changing teachers' professional work in mathematics: One school's journey. In T. A. Romberg, T. P. Carpenter, & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 209-230). Mahwah, NJ: Erlbaum.
- Franke, M. L., Kazemi, E., & Battey, D. (2007). Mathematics teaching and classroom practice. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 225-256). Greenwich, CT: Information Age Publishers.
- Franke, M., Grossman, P., Hatch, T., Richert, A., & Schultz, K. (2006). *Using representations of practice in teacher education*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

- Gallucci, C. (2008). Using sociocultural theory to link professional learning to organizational support in the context of school district instructional reform. *American Journal of Education*, 114, 541–581.
- Gamse, B. C., Jacob, R. T., Horst, M., Boulay, B., & Unlu, F. (2008). *Reading First impact study final report* (NCEE 2009-4038). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.
- Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4).
- Gearhart, M., Nagashima, S., Pfothauer, J., Clark, S., Schwab, C., Vendlinski, T., et al. (2006). Developing expertise with classroom assessment in K–12 science: Learning to interpret student work interim findings from a 2-year study. *Educational Assessment*, 11, 237-263.
- Gibbons, L. K., (2012). How aspects of the school setting and coach characteristics influence coach centrality. (Unpublished doctoral dissertation). Vanderbilt University, Nashville, TN.
- Goffman, E. (1981). *Forms of talk*. Philadelphia: University of Pennsylvania Press.
- Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. W. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, 111(9), 2055-2100.
- Grossman, P., & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. *American Educational Research Journal*, 45(1), 184-205.
- Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching, Theory and Practice*, 15(2), 273-289.
- Guskey, T. R. (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.
- Hayes, R. S. (2010). The study of literacy coaching observations and interviews with elementary teachers. (Doctoral dissertation). Retrieved from Educational Policy Studies Dissertations. Paper 53. http://digitalarchive.gsu.edu/eps_diss/53
- Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K. C., Wearne, D., & Murray, H. (1997). *Making Sense: Teaching and Learning Mathematics with Understanding*. Portsmouth, NM: Heinemann.

- Hill, H. C. (2007). Learning in the teaching workforce. *Future of Children*, 17(1), 111-127.
- Hill, H., Rowen, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, 20(2), 371-406.
- Horn, I.S. (2005). Learning on the job: A situated account of teacher learning in high school mathematics departments. *Cognition & Instruction*, 23(2), 207-236.
- Horn, I.S. (2007). Fast kids, slow kids, lazy kids: Framing the mismatch problem in math teachers' conversations, *Journal of the Learning Sciences*, 16(1), 37-79.
- Horn, I. S. (2010). Teaching replays, teaching rehearsals, and re-revisions of practice: Learning from colleagues in a mathematics teacher community. *Teachers College Record* 112(1), 225-229.
- Horn, I. S., & Little, J. W. (2010). Attending to problems of practice: Routines and resources for professional learning in teachers' workplace interactions. *American Educational Research Journal*, 47(1), 181-217.
- Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practices, student outcomes and efficacy. *Education Policy Analysis Archives*, 13(10). Retrieved March 25, 2012 from <http://epaa.asu.edu/epaa/v1310>
- Jackson, K., Shahan, E., Gibbons, L., & Cobb, P. (accepted for publication). Setting up complex tasks. *Mathematics Teaching in the Middle School*.
- Jackson, K., Garrison, A., Wilson, J., Gibbons, L., & Shahan, E. (2011, April). *Investigating how setting up cognitively demanding tasks is related to opportunities to learn in middle-grades mathematics classrooms*. Paper presented at the Research Pre-session of the National Council of Teachers of Mathematics Annual Meeting, Indianapolis, IN.
- Jacobs, J. K., Hollingsworth, H., & Givvin, K. B. (2007). Video-based research made "easy": Methodological lessons learned from the TIMSS video studies. *Field Methods*, 19(3), 284-299.
- Jacobsen, C. and Lehrer, R. (2000), Teacher appropriation and student learning of geometry through design, *Journal for Research in Mathematics Education*, 31(1), 71-88.

- Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, 7, 203–235.
- Kazemi, E., Franke, M. L., & Lampert, M. (2009). *Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction*. Paper presented at the annual meeting of the Mathematics Education Research Group of Australasia, Wellington, New Zealand.
- Kazemi, E., Lampert, M., & Ghouseini, H. (2007). *Conceptualizing and using routines of practice in mathematics teaching to advance professional education*. Report to the Spencer Foundation.
- Kazemi, E., Elliott, R., Hubbard, A., Carroll, C., & Mumme, J. (2007). Doing mathematics in professional development: Theorizing teacher learning with and through sociomathematical norms. In T. de Silva Lamberg & L. R. Wiest (Eds.), *Proceedings of the twenty ninth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 796-803). Lake Tahoe: University of Nevada, Reno.
- Kazemi, E., & Hubbard, A. (2008). New directions for the design and study of professional development: Attending to the coevolution of teachers' participation across contexts. *Journal of Teacher Education*, 59, 428-441.
- Kazemi, E., & Hintz, A. (2008). *Fostering productive mathematical discussions in the classroom*. Unpublished manuscript. Seattle, WA: University of Washington.
- Kilpatrick, J., Swafford, J., and Findell, B. (Eds.) (2001). *Adding it up: Helping children learn mathematics*. Washington, D.C.: National Academy Press.
- Knapp, M. S. (2003). Professional development as policy pathway. *Review of Research in Education*, 27(1), 109-157.
- Koellner, K., Schneider, C., Roberts, S., Jacobs, J., & Borko, H. (2008). Using the Problem-Solving Cycle Model of professional development to support novice mathematics instructional leaders. In *Association of Mathematics Teacher Educators Monograph V*. San Diego, CA: AMTE.
- L'Allier, S., Elish-Piper, L., & Bean, R (2010). What matters for elementary literacy coaching? Guiding principles for instructional improvement and student achievement. *The Reading Teacher*, 63, 544–554.
- Lampert, M. (2010). Learning in, from and for practice: What do we mean? *Journal of Teacher Education* 61(1-2), 21-24.

- Lampert, M., & Ball, D. L. (1998). *Teaching, multimedia, and mathematics: Investigations of real practice*. New York: Teachers College Press.
- Lampert, M., Beasley, H., Ghouseini, H., Kazemi, E., & Franke, M. L. (2010). Using designed instructional activities to enable novices to manage ambitious mathematics teaching. In M. K. Stein & L. Kucan (Eds.), *Instructional explanations in the disciplines* (pp. 129-141). New York: Springer.
- Lampert, M., & Graziani, F. (2009). Instructional activities as a tool for teachers' and teacher educators' learning. *The Elementary School Journal*, 109(5), 491-509.
- Lappan, G. (1997). The challenges of implementation: Supporting teachers. *American Journal of Education*, 106, 207-239.
- Lappan, G., & Ferrini-Mundy, J. (1993). Knowing and doing mathematics: A new vision for middle grades students. *The Elementary School Journal*, 93(5), 625-641.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Little, J. W. (1982). Norms of collegiality and experimentation: Workplace conditions of school success. *American Educational Research Journal*, 19(3), 325-340.
- Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, 15, 129-151.
- Little, J. W. (2002). Locating learning in teachers' communities of practice: opening up problems of analysis in records of everyday work. *Teaching and Teacher Education*, 18(7), 917-946.
- Little, J. W. (2003). Inside teacher community: Representations of classroom practice. *Teachers College Record*, 105(6), 913-945.
- Little, J. W., Gearhart, M., Curry, M., & Kafka, J. (2003). Looking at student work for teacher learning, teacher community, and school reform. *Phi Delta Kappan*, 85, 184-192.
- Little, J. W. (2004). "Looking at student work" in the United States: Countervailing impulses in professional development. In C. Day & J. Sachs (Eds.), *International handbook on the continuing professional development of teachers* (pp. 94-118). Buckingham, UK: Open University Press.
- Little, J. W. (2007). Teachers' accounts of classroom experience as a resource for professional learning and instructional decision making. In P. A. Moss (Ed.), *Evidence and decision-making: The 106th yearbook of the National Society for the Study of Education, Part I* (pp. 217-240). Malden, MA: Blackwell Publishing.

- Little, J. W., & Horn, I. S. (2007). "Normalizing" problems of practice: Converting routine conversation into a resource for learning in professional communities. In L. Stoll & K. S. Louis (Eds.), *Professional learning communities: Divergence, depth, and dilemmas* (pp. 79-92). New York: Open University Press.
- Lo, J. J., Grant, T. J., & Flowers, J. (2008). Challenges in deepening prospective teachers' understanding of multiplication through justifications. *Journal of Mathematics Teacher Education*, 11, 5-22.
- Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.
- Louis, K. S., Marks, H. M., & Kruse, S. (1996). Teachers' Professional Community in Restructuring Schools. *American Educational Research Journal*, 33, 757-798.
- Mangin, M. M. (2005). Teacher leadership and instructional improvement: Teachers' perspectives. In W. K. Hoy & C. Miskel (Eds.), *Contemporary issues in educational policy and school outcomes* (pp. 159-192). Greenwich, CT: Information Age Publishing.
- Mangin, M. M. (2007). Facilitating Elementary Principals' Support for Instructional Teacher Leadership. *Educational Administration Quarterly*, 43(3), 319-357.
- Marsh, J., McCombs, J., Lockwood, J. R., Martorell, F., Gershwin, D., Naftel, S., Le, V., Shea, M., Barney, H., & Crego, A. (2008). Supporting literacy across the sunshine state: A study of Florida middle school reading coaches. Santa Monica, CA: Rand Corporation. http://www.rand.org/pubs/research_briefs/RB9374/
- Matsumura, L. C., Sartoris, M., Bickel, D. D., & Garnier, H. E. (2009). Leadership for literacy coaching: The principal's role in launching a new coaching program. *Educational Administration Quarterly* 45(5) 655-693.
- Matsumura, L. C., Garnier, H. E., Resnick, L. (2010). Implementing literacy coaching: The role of school social resources. *Educational Evaluation and Policy Analysis*, 32(2), 249-272.
- May, P. J. (2010). *Literacy coaching: The role of reflective thought in teacher decision making*. (Master's Theses), Retrieved from Dissertations Graduate and Research Overview. Paper 32. <http://digitalcommons.ric.edu/etd/34>
- McLaughlin, M., & Talbert, J. E. (1993). *Contexts that matter for teaching and learning: Strategic opportunities for meeting the nation's educational goals*. Stanford, CA: Center for Research on the Context of Secondary School Teaching, Stanford University.

- McLaughlin, M. W., & Talbert, J. E. (2006). *Building school-based teacher learning communities: Professional strategies to improve student achievement*. New York: Teachers College Press.
- Milne, C., Scantlebury, K., Blonstein, J., & Gleason, S. (2011). Coteaching and disturbances: Building a better system for learning to teach. *Research in Science Education* 41(3), 413-440.
- National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: author.
- National Council of Teachers of Mathematics (1991). *Professional Standards for Teaching Mathematics*. Reston, VA: author.
- National Council of Teachers of Mathematics (1995). *Assessment Standards for School Mathematics*. Reston, VA, author.
- National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: author.
- Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity, promises and practicalities*. Washington, DC: Aspen Institute Program on Education and Annenberg Institute for School Reform.
- Olson, J., & Barrett, J. (2004). Coaching teachers to implement mathematics reform recommendations. *Mathematics Teacher Education and Development*, 6(63-78).
- Penuel, W. R., Riel, M., Krause, A. E., & Frank, K. A. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record*, 111(1), 124-163.
- Poglinco, S. M., Bach, A., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003). *The heart of the matter: The coaching model in America's Choice schools*. Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.
- Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4-15.
- Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. Oxford: Oxford University Press.
- Ross, J. (1992). Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education*, 17(1), 51-63.

- Roth, W. M. (1998a). Science teaching as knowledgeability; A case study of knowing and learning during co-teaching. *Science Education*, 82, 357-377.
- Roth, W. M. (1998b). Teaching and learning as everyday activity. In B. J. Fraser, & K. Tobin (1998b). *International handbook of science education* (pp. 169-181). Dordrecht, Netherlands: Kluwer Academic Publishing.
- Roth, W.-M., Masciotra, D., & Boyd, N. (1999). Becoming in the classroom: A case study of teacher development through coteaching. *Teaching and Teacher Education*, 17, 771-784.
- Roth, W.-M., & McRobbie, C. (1999). Lifeworlds and the 'w/ri(gh)ting' of classroom research. *Journal of Curriculum Studies*, 31, 501-522.
- Roth, W. M., & Tobin, K. (2001). The implications of coteaching/cogenerative dialogue for teacher evaluation: Learning from multiple perspectives of everyday practice. *Journal of Personnel Evaluation in Education*, 15, 7-29.
- Roth, W. M., & Tobin, K. G. (2002). *At the elbow of another: Learning to teach by co-teaching*. New York: Peter Lang.
- Roth, W. M., & Tobin, K. G. (Eds.). (2005). *Teaching together, learning together*. New York: Peter Lang.
- Roth, W. M., Tobin, K. G., Carambo, C., Dalland, C. (2004). Coteaching: Creating resources for learning and learning to teach chemistry in urban high schools. *Journal of Research in Science Teaching* 41(9), 882-904.
- Sailors, M. & Price, L. (2010). Professional development that supports the teaching of cognitive reading strategy instruction. *The Elementary Journal*, 110(2), 301-322.
- Santagata, R. (2009). Designing video-based professional development for mathematics teachers in low-performing schools. *Journal of Teacher Education*, 60(1), 38-51.
- Scantlebury, K, Gallo-Fox, J, & Wassell, B (2008). Co-teaching as a model for successful teaching. *Teaching and Teacher Education*, 24(4), 967-981.
- Schifter, D. (1998). Learning mathematics for teaching: From a teachers' seminar to the classroom. *Journal of Mathematics Teacher Education*, 1, 55-87.
- Schifter, D., Bastable, V., & Russell, S. J. (1997). Attention to mathematical thinking: Teaching to the big ideas. In S. Friel & G. Bright (Eds.), *Reflecting on our work: NCTM enhancement in K-6 mathematics* (pp. 255-261). New York: University Press of America.

- Schifter, D. & Fosnot, C.T. (1993). *Reconstructing mathematics education: Stories of teachers meeting the challenge of reform*. New York: Teachers College Press.
- Schifter, D. & Simon, M.A. (1992). Assessing teachers' development of a constructivist view of mathematics learning. *Teaching and Teacher Education*, 8, 187–197.
- Schon, D. (1987). *Educating the reflective practitioner*. San Francisco, CA: Jossey-Bass.
- Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Advances in research on teaching: Using video in teacher education*, 10 (1-27). Oxford, UK: Elsevier.
- Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of video club. *Teaching and Teacher Education*, 20, 163-183.
- Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, 13(3), 475-491.
- Simon, M.A. & Schifter, D.E. (1991). Towards a constructivist perspective: An intervention study of mathematics teacher development. *Educational Studies in Mathematics*, 22, 309–331.
- Smith, M. S., Bill, V. & Hughes, E. K. (2008). Thinking through a lesson: Successfully implementing high-level tasks. *Mathematics Teaching in the Middle School*, 14, 132-138.
- Spillane, J. P., Reiser, B., & Gomez, L. M. (2006). Policy implementation and cognition: The role of human, social, and distributed cognition in framing policy implementation. In M. I. Honig (Ed.), *New directions in educational policy implementation* (pp. 47-64). Albany, NY: State University of New York Press.
- Staples, M. (2007). Supporting whole-class collaborative inquiry in a secondary mathematics classroom. *Cognition and Instruction*, 25(2), 161-217.
- Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal*, 33, 455-488.
- Stein, M. K., Silver, E. A., & Smith, M. S. (1999). Mathematics reform and teacher development: A community of practice perspectives. In J. Greeno & S. Goldman (Eds.), *Thinking practices: A symposium on mathematics science and learning*. Hillsdale, NJ: Lawrence Erlbaum.

- Stein, M. K., Smith, M. S., Henningsen, M. A., & Silver, E. A. (2000). *Implementing standards-based mathematics instruction: A casebook for professional development*. New York: Teachers College Press.
- Supovitz, J. A., Mayer, D. P., & Kahle, J. B. (2000). Promoting inquiry based instructional practice: The longitudinal impact of professional development in the context of systemic reform. *Educational Policy* 14(3), 331-356.
- Suzuka, K., Sleep, L., Ball, D. L., Bass, H., Lewis, J. M., & Thames, M. H. (2010). Designing and using tasks to teach mathematical knowledge for teaching. In D. Mewborn & H. S. Lee (Eds.), *Association of Mathematics Teacher Educators Monograph VI: Scholarly practices and inquiry in the preparation of mathematics teachers*. San Diego, CA: AMTE.
- Teemant, A., Tyra, S., & Wink, J. (2009, May). *Evaluating the effectiveness of the CREDE coaching model*. Paper presented at the CREDE Conference, San Francisco, CA.
- Tharp, R. G. & Gallimore, R. *Rousing Minds to Life: Teaching, Learning, and Schooling in Social Context*. Cambridge: Cambridge University Press.
- Thompson, C. L., & Zeuli, J. S. (1999). The frame and tapestry: Standards-based reform and professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341-375). San Francisco: Jossey-Bass.
- Thompson, J., Braaten, M., Windschitl, M., Sjoberg, B., Jones, M., & Martinez, K. (2009b). Examining Student Work: Evidence-based learning for students and teachers. *The Science Teacher*, 76(8), 48-52.
- Tobin, K. (2006). Learning to teach through coteaching and cogenerative dialogue. *Teaching Education*, 17, 133-142.
- Tobin, K., & Roth, W. M. (2006). *Teaching to Learn: A View from the Field*. Rotterdam, NL: Sense Publishing.
- Tobin, K., Seiler, G., & Smith, M. W. (1999a). Educating science teachers for the sociocultural diversity of urban schools. *Research in Science Education*, 29, 68-88.
- U.S. Department of Education. (2008). *The final report of the National Mathematics Advisory Panel*. Washington, DC: Author.
- Villasenor, A., & Kepner, H. S. 1993. Arithmetic from a Problem-Solving Perspective: An Urban Implementation. *Journal for Research in Mathematics Education*, 24, 62-70.

- van Es, E. A., & Sherin, M. G. (2006). How different video club designs support teachers in "learning to notice". *Journal of Computing in Teacher Education*, 22(4), 125-135.
- van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, 24, 244–276.
- van Es, E.A. & Sherin, M.G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, 13, 155- 176.
- Van Keer, H., & Verhaeghe, J. P. (2005). Comparing two teacher development programs for innovating reading comprehension instruction with regard to teachers' experiences and student outcomes. *Teacher and Teacher Education*, 21, 543-562.
- Villasenor, A., & Kepner, H. S. (1993). Arithmetic from a problem-solving perspective: An urban implementation. *Journal for Research in Mathematics Education*, 24(1), 62-69.
- Vygotsky, L. S. (1978). Interaction between learning and development. In *Mind in society: The development of higher psychological processes* (pp. 79-91). Cambridge, MA: Harvard University Press.
- West, L., & Staub, F.C. (2003). *Content-focused coaching: Transforming mathematics lessons*. Portsmouth, NH: Heinemann / Pittsburgh, PA: University of Pittsburgh.
- Windschitl, M., Thompson, J., Braaten, M., Stroupe, D., Chew, C., & Wright, B. (2010, April). The beginner's repertoire: A core set of instructional practices for teacher preparation. Paper presented at the annual meeting of the American Educational Research Association, Denver, CO.
- Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 173-210). Washington, DC: American Educational Research Association.
- Zhang, M., Lundeberg, M., Koehler, M. J., & Eberhardt, J. (2011). Understanding affordances and challenges of three types of video for teacher professional development. *Teaching and Teacher Education*, 27(2), 454-462.
- Zhao, Q. (2011). *Reconceptualizing Supporting Teachers' Learning Across the Settings of Professional Development and the Classroom*. (Unpublished doctoral dissertation). Vanderbilt University, Nashville.

Appendix A

Figure 1
<i>Initial List of Activities Identified to Examine Against Characteristics of Professional Learning Opportunities</i>
Analyzing classroom video
Analyzing test data
Assist with school improvement plan
Attend professional conferences
Book study
Classroom visitation
Co-planning for upcoming instruction
Co-teaching
Coaching cycle
Compiling teacher portfolios
Conducting action research
Debriefing challenges of implementation
Doing mathematics
Examining student work
Examining various textbooks for adoption
Journaling about experiences
Leadership development programs
Lesson study
Mapping the standards to the curriculum
Modeling instruction
One-time workshops about particular teaching strategy or mathematical idea
Receiving feedback after observation
Rehearsing aspects of instructional practice
Viewing educational videos
Writing math tasks/curriculum development

Appendix B

Figure 2	
<i>Search Terms used To Identify Professional Learning Studies that Examined Specific Activities.</i>	
Activity	Search Terms
Doing Mathematics	“doing mathematics + professional development”, “mathematics content + professional development”, “mathematics content + teacher education”
Examining Student Work	“examining student work”, “examining student work + professional development”, “examining student work + teacher education”
Analyzing Classroom Video	“analyzing classroom video”, “examining classroom video”, “examining video + education”, “analyzing video + professional development”, “analyzing video + teacher education”, “cycles of investigation”
Rehearsing Aspects of Practice	“cycles of enactment”, “micro-teaching”, “rehearsing instruction in teacher education”, “rehearsals + education”
Co-teaching	“co-teaching”, “apprenticeship + education”, “guided practice”
Modeling	“modeling”, “demonstration teaching”
Observing and providing feedback (or coach cycle)	“instructional supervision + teacher education”, “feedback + student teaching”, “university supervisor + teacher education”, “cooperating teacher + student teaching”, “providing feedback to novice teachers”, “teacher induction + feedback”, “mentoring + feedback”
Debriefing challenges of implementation	“debriefing”

CHAPTER III

HOW ASPECTS OF THE SCHOOL SETTING AND COACH CHARACTERISTICS INFLUENCE COACH CENTRALITY

Introduction

There is increasing evidence that teachers' professional communities and access to expertise play an important role in instructional improvement (Coburn & Russell, 2008; Coburn, 2001; Elmore, Peterson, & McCarthy, 1996; Frank, Zhao, & Borman, 2004; Louis, Marks, & Kruse, 1996; Penuel, Riel, Krause & Frank, 2009). Many district reform initiatives include time for teachers to meet and the provision of content-focused coaches as a means to provide teachers continuous, job-embedded support (Coburn & Russell, 2008; McLaughlin & Talbert, 2006; Poglinco, Bach, Hovde, Rosenblum, Saunders & Supovitz, 2003; Neufled & Roper, 2003; Darling-Hammond, Wei, Andree, Richardson & Orphanos, 2009). In this study, we investigated a mathematics coaching design in which coaches are intended to play a central role in supporting the improvement of middle school mathematics teaching at scale.

The data for this study comes from the second year of a four-year study in which we⁴ investigated how changes in the school and district settings in which mathematics teachers work influence their instructional practices, students' learning opportunities, and students' mathematics achievement. The collaborating districts are attempting to promote ambitious instruction in mathematics through the use of NSF-funded curricula

⁴ The Designing Learning Organizations for Instructional Improvement in Mathematics Study is funded by the NSF, award No. ESI 0554535. Paul Cobb (Co-PI), Tom Smith (Co-PI), Erin Henrick (Project Manager), Glenn Colby, Annie Garrison, Lynsey Gibbons, Kara Jackson, Karin Katterfeld, Chuck Munter, Rebecca Schmidt, Jonee Wilson

and other supports for teachers. In order to use the adopted curricula, many teachers need significant learning opportunities to be able to reorganize their instructional practices, rather than merely adjusting and elaborating on current practices. Content-focused coaching is one such support that the districts have selected to implement.

In this study, we focused on the centrality of school-based middle school mathematics coaches within the schools they serve in one district (District B). We focus on District B because the coaching design intends that mathematics coaches will become a central source of expertise for teachers on matters of mathematics instruction. In other words, district leaders intend for coaches to support all of the mathematics teachers in the schools they serve. Principals at each middle school selected a mathematics coach to teach for the first half of the day (either 6th, 7th, or 8th grade students) and to coach teachers during the second half of the day. This design employed half-day, school-based coaches to support middle grades teachers in developing their instructional practices.

Based on a review of the relevant literature, we developed a list of conjectures that may influence middle school mathematics coaches to become a central source of expertise (i.e., a majority of teachers go to the coach for advice or information about teaching mathematics) and analyzed interviews to investigate the conjectured influences. We then employed qualitative and social network analyses to analyze how central coaches are within teachers' social networks and uncover what influenced their centrality. We provide evidence that specific aspects of school-level contexts, including time to meet with groups of teachers to collaborate on matters of instruction and support from the principal, influence coaches' in becoming a central source of expertise. By identifying aspects of the school-level contexts that support mathematics coaches to become a central

source of expertise, we indicate several issues that districts should consider when creating conditions to facilitate interactions between the mathematics coach, mathematics teachers, and principals.

Mathematics Coaching

The goal of content-focused coaching is to provide opportunities for development through ongoing collaborative work between the coach and individual or groups of teachers in order to develop intellectual capacity in a school (Poglinco, et al., 2003; Neufeld & Roper, 2003). Content-focused coaching designs, and specifically mathematics coaching, are one of the main mechanisms to provide teachers access to expertise in developing new mathematical practices in their classrooms. A few studies show that teachers' access to instructional expertise is associated with instructional improvement (Frank, Zhao & Borman, 2004; Penuel, et al., 2009), and researchers who have examined teacher professional development argue that teachers' co-participation in activities of sufficient depth with an accomplished colleague is a critical source of support for teachers' development of ambitious practices (Cobb & Smith, 2008; Borko, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Wilson & Berne, 1999).

Large sums of money are being allocated by school districts every year to implement mathematics coaching designs. Mathematics coaching appears to be a plausible way to provide ongoing professional development to teachers who are attempting to implement high quality mathematics instruction. However, the empirical and theoretical literature on content-focused coaching, and especially mathematics coaching, is very limited. Even with the promise of coaching for supporting new forms

of instructional practices, very few studies have assessed the direct impact of content-focused coaching on instruction and learning, and the results from such studies have yielded mixed results (Garet, Porter, Desimone, Birman, & Yoon, 2008; Neufeld & Roper, 2003; Ross, 1992). A few of the research studies indicate that content-focused coaching can have a positive effect on the development of teacher efficacy, implementation of new instructional techniques, and student achievement (Campbell & Malkus, 2011; Cantrell & Hughes, 2008; Marsh, McComb, Lockwood, Martorell, Gershwin, & Naftel, 2008; Matsumura, Garnier, & Resnick, 2010; Ross, 1992; Sailors & Price, 2010). Some studies showed no effect on instructional improvement (Gamse, Jacob, Horst, Boulay, & Unlu, 2008; VanKeer & Verhaeghe, 2005). Variable implementation is one reason why the research evidence is mixed. This variation can take form in the amount and type of coaching that teachers receive, which has been shown to be substantively different across schools (Matsumura, Sartoris, Bickel, Garnier, 2009; Coburn & Russell, 2008). Therefore, schools within the same district may have different forms and quality of support provided to teachers by mathematics coaches. Because of this, coaching policies and programs appear to be vulnerable to the same contextual complexities as other educational reforms (Coburn, 2001, 2006; Coburn & Stein, 2006; Matsumura, et al., 2009).

School-level Contexts

We now turn to discuss our conjectures about what might influence coaches to become central within teachers' social networks. We conjecture that the following may influence whether or not the teacher turns to the coach for assistance: the coach's

expertise in matters of mathematics instruction and teachers' perceptions of the coach as someone who is capable of assisting them. Current research provides a number of examples of school-level contextual influences that can help to explain variable implementation and success of content-focused coaching designs. These are: structural aspects of the school (e.g., size of the schools, time for groups of teachers to meet with the coach) and the amount and type of support provided by the principal. We now discuss these conjectured influences in greater detail.

Coach Characteristics

Coach expertise in matters of mathematics instruction. It is important to consider what coaches know and can do as mathematics teachers because this may influence whether a teacher turns to a coach for advice about mathematics instruction. In a study conducted by Coburn and Russell (2008), they found that the presence of a mathematics coach had different implications for teachers' access to a knowledgeable other, because the coaches had different levels of expertise. If coaches themselves have ambitious instructional practices and have developed rich understandings of mathematical knowledge for teaching (Ball, Hill & Bass, 2005; Shulman, 1986; 1987), then we conjecture that it is more likely that they will be able to support teachers to develop ambitious forms of practices, and therefore, are likely to be more central within teachers' social networks. For this study, we will consider differences in what coaches know and can do as expert mathematics teachers and how this influences centrality.

Teachers' perceptions of the coach. In addition to school-level contexts, it will be important to attend to the teachers' perceptions of the coach and examine why teachers

choose to form relationships with coaches. Bryk and colleagues (2010) describe relationships as an essential part of change in a school community, and critical to this is relational trust. They suggest that individuals are constantly engaged in a process of discerning the intentions embedded in the actions and exchanges of others; this can include: 1) the history of interactions that have taken place, 2) interpersonal contact, and 3) evaluation about competence. In this study, it will be important to examine how teachers' prior history with coaches, their evaluations of interpersonal contact with coaches, and their perceptions of coaches as individuals who are knowledgeable about teaching mathematics (e.g., has a solid mastery on the mathematics content) influence whether or not they choose to go to the coach for advice or information about teaching mathematics.

Structural Aspects of the School

Time to meet with groups of teachers. Studies have indicated the importance of collegial relationships as a factor influencing teacher learning about instruction (Coburn & Russell, 2008; Darling-Hammond et al., 2009; Horn & Little, 2010; Louis & Kruse, 1995) and in school improvement (Bryk, Sebring, Allensworth, Luppescu, & Easton, 2009; Little, 1982; Louis, Marks, & Kruse, 1996; McLaughlin & Talbert, 2001). Some school districts have responded to these ideas through promoting “professional learning communities” at the school and district levels (Horn & Little, 2010; Hargreaves, 2007). While researchers have acknowledged the importance of including a more knowledgeable other in such learning communities (Louis & Kruse, 1995), prior studies have not examined how coaches' participation in collaborative meetings with teachers has

influenced coach effectiveness. We will examine how teacher collaborative meetings influences the centrality of coaches within teachers' social networks.

Size of school. Related to our conjecture about the importance of coaches having time to meet with groups of teachers, we believe that coaches also need to be available to spend time with teachers individually in order to provide them specific assistance.

Therefore, we conjecture that an additional influence of centrality may be the size of the school. In many districts, including District B's design, there are differences in the size of the schools and thus the number of mathematics teachers in each school. The difference in size influences the number of teachers a coach is expected to work with, as well as the amount of time the coach gets to spend with each teacher. We conjecture that coaches might be more central in smaller schools, where coaches have more time to spend with each teacher.

Support Provided by the Principal

Several prior investigations of content-focused coaching indicate that coaches require the support and backing of school principals to effectively perform their responsibilities (Grant & Davenport, 2009; Mangin, 2005; Smylie, Conley & Marks, 2002; Youngs & King, 2002; Marks & Printy, 2003). Some empirical evidence exists that indicates that principal support for coaches varies (Mangin, 2007), and that principals can positively influence the work of mathematics coaches (e.g., having a positive influence on getting access to teachers' classrooms) (Matsumura, et al., 2009). Mangin (2007) found evidence of a link between principals' knowledge of the role of the coach, their communication with the coach, and their support for coaching. Those principals

that were highly supportive repeatedly communicated to teachers an expectation of instructional improvement, while simultaneously described the coaches as a useful instructional resource to teachers. Matsumura and colleagues (2009) found that principals' beliefs regarding the literacy coach's role and responsibilities were associated with the frequency with which teachers opened their classrooms to the new coaches. They also found that principal leadership (defined as actively participating in the content-focused coaching program and publicly endorsing the coach as a source of literacy expertise) was significantly associated with the frequency with which teachers conferred with the coach and were observed by the coach as they taught reading comprehension lessons.

In addition to attending professional development about the coaching program (Matsumura et al., 2009) and publicly endorsing the coach (Mangin, 2007; Matsumura et al., 2009), we conjecture that additional principal practices will influence the extent to which a coach is central within teachers' social networks. Additional practices include the principal meeting with coaches on a regular basis in order to discuss the learning needs of the mathematics department and individual teachers is important to support the coaches work with teachers. If both the principal and coach regularly observe classroom instruction, then together they can discuss teachers' current practices and consider the types of support teachers need either through working one-on-one with the coach or through a teacher collaborative meeting led by the coach. Therefore, we will examine important differences between how principals support coaches directly (e.g., regularly meeting with coaches) and indirectly (e.g., by providing time for teachers to meet with the coach) by looking for differences in their practices as instructional leaders.

Teacher Social Networks

Many districts are currently allocating numerous resources to support the implementation of mathematics coaching programs. In many coaching designs across the US, the coach is intended to be a central source of expertise for teachers and principals. It is worthwhile to investigate what it takes to get a return on this investment. Penuel and colleagues (2009) suggested that social network analysis of teachers in a school offers a method for understanding how teachers' interactions relate to instructional improvement. They further argue that a network perspective can be used to "analyze the efficacy of reform coaches for improving teachers' access to expertise and resources and for facilitating the change process" (p.126). In our analysis of social network data, we adopt a social capital perspective where individuals interact with others to gain access to resources for advancement (Coleman, 1990; Lin, 2001; Portes, 1998). Applied to teachers within schools, the theory implies that through interactions with other individuals (teachers, coaches, school leaders, or other support staff), teachers access instructional expertise and other resources that help them improve their instructional practices or achieve other professional goals.

As mentioned previously, by providing mathematics coaches, districts attempt to give teachers access to expertise and other resources to assist them in developing high quality instructional practices. The extent to which teachers seek advice or information from the coach relates to how effective the coach is in supporting teachers' instructional improvement. Within the field of social network analysis, measures of network centrality quantify the existence and density of ties to particular individuals. Network centrality is often related to power or influence, but can be defined and interpreted in many different

ways (Hanneman & Riddle, 2005). In this case, our examination of coach centrality is more closely related to measuring influence than power (our choice of a measure is explained in the subsequent section).

District and school leaders can create conditions for the development of particular types of social interactions (e.g., teachers co-planning together in common planning time), but the social relations and networks are emergent phenomena that continually regenerate in the course of ongoing interactions (Coburn & Russell, 2008; Smylie & Evans, 2006; Spillane, Reiser & Gomez, 2006). By analyzing social network data, we are able to examine the interactions between individuals within the school as they relate to supporting teachers' instructional improvement. Supplementing these measures with interview data allows us to explore how aspects of the school setting and coach characteristics directly influence coach centrality at the school level and, more indirectly, at the level of individual teachers' decisions about seeking advice from the coach. By doing this, we can better understand how district and school leaders can create conditions for coaches to be central sources of expertise for the teachers in their schools.

District B

District B is a large urban district, located in the United States. Serving nearly 80,000 students across the district, of which approximately 70% were identified as economically disadvantaged, 30% as English Language Learners, and 10% as students with disabilities⁵. The racial and ethnic make-up were approximately 15% white, 25% black, 60% Hispanic, 2% Asian or Pacific Islander, and 1% American Indian or Alaska

⁵ Demographic information for the district and each participating school was gathered from schooldatadirect.org. It is for the 2008-2009 school year, which is the year in which we collected the data analyzed in this paper.

Native. District B students consistently scored lower on state achievement tests in mathematics than other districts in the state, and there were persistent achievement disparities between students of color and their white counterparts. District B has recently undertaken instructional reform in middle-grades mathematics. The district adopted the NSF-funded curriculum *Connected Mathematics Project 2* (CMP2) and implemented in the 2007-2008 school year. At the time of the study, the district was in its second year of implementation. In order to support teachers in implementing CMP2, district leaders created the position of school-based mathematics coaches. We now describe the design for coaching in District B.

Description of District B's Design for Mathematics Coaching

In order to understand District B's coaching design, we interviewed key district leaders from the offices of Leadership and Curriculum and Instruction (including the mathematics department) in the fall of 2008. We asked district leaders to describe the intended role of the coach and how coaches were supported both at the district- and school-level. The district was in its fourth year of using the mathematics coaches in each school⁶. As described previously, District B's coaches were school-based teacher leaders, hired by the principal, who taught for half of the school day and coached for the other half. Leaders described four goals for the coaches: (1) provide one-on-one instructional support to their colleagues in the classroom (e.g., model instruction, provide feedback), (2) act as a resource for the principal in matters of mathematics content (e.g., observe instruction alongside the principal in order have conversations about what they

⁶ The district also supports other content-focused coaches in each middle school for science, social studies, and English.

notice), (3) provide professional development to all middle school mathematics teachers on district professional development days (e.g., workshops on examining student work), and (4) provide professional development support to their colleagues at their school (e.g., continue discussions about how to use student work in their practice). In addition, district leaders specifically mentioned that the coach is to be a supporter rather than an evaluator of teachers.

District leaders also supported the mathematics coaches by providing them with sustained professional development. Two years prior to adopting and implementing CMP2, the district provided sustained professional development to the mathematics coaches, giving them opportunities to interact with the curriculum and consider how teachers would need to reorganize their instructional practices in order to use the curriculum to create high quality learning opportunities for students. For example, in the 2006-2007 school year, the district sent the coaches to a weeklong, intensive professional development seminar led by the curriculum designers at Michigan State University where the coaches examined the investigations in the CMP2 curriculum. In addition, district leaders provided coaches with additional supports, such as training in cognitive coaching (asking teachers specific questions to help them reflect on their practice), in preparation for coaches to support teachers, many for the first time. District mathematics specialists provided support for individual coaches at their schools. Finally, district leaders indicated that prior to the beginning of the school year, they had worked closely with coaches and principals in order to come to a shared understanding of what the coaches' responsibilities were when working with teachers during their coaching time.

Participants

In order to understand how middle grades mathematics teachers were being supported to implement high quality instructional practices within their classrooms, we worked with district leaders to choose a representative sample of middle schools for the full study. Seven middle schools were selected to be representative of the range of capacity for improvement of middle schools in the district. Within those schools, mathematics teachers were recruited to be a part of the study. Approximately 5 mathematics teachers were randomly selected at each school. Principals and coaches were also asked to participate along with an assistant principal, if he or she was identified as someone who was responsible for mathematics instruction. Across our sample of seven schools, 32 teachers, 7 coaches, and 9 school leaders participated in the full study. In order to examine teacher networks, we collected additional data by requesting that all of the mathematics teachers within each school to provide information about who they went to for advice or information about teaching mathematics (as will be explained further in the data section).

Methods

Data

Data collected includes 1) an online network survey sent to all mathematics teachers within the schools, asking them to indicate who they turn to for advice or information about teaching mathematics, and 2) audio-recorded interviews conducted

with school-level full participants—mathematics teachers, coaches, and principals—to understand participants work at their schools and the larger school context.

Network survey. In order to understand how many teachers turn to coaches for advice or information about mathematics (and therefore, the role of coaches in teacher social networks in each school), we drew on information from an online network survey sent in March 2009 to every mathematics teacher ($n=70$) in each of the 7 schools asking teachers to indicate who they turn to for advice or information about mathematics. We attempted to survey all mathematics teachers in the school, rather than just participants of the full study, to have a complete understanding of the math teacher social network within the school. On the survey, teachers typed in the name and role within the school (e.g., math coach) of the person from whom they seek advice or information about teaching mathematics, and provided additional information about the frequency, influence, and content of those interactions. To be further described in the following section, this study's analysis of the social network data focuses on the existence of interactions rather than their influence or content.

Interviews. In order to understand the participants' (teachers, coaches, and school leaders) perceptions of the coach's role, all participants were asked to describe what they understand to be the role of the coach. To uncover the amount and type of support provided by the principal, principals were asked to describe whether they met with coaches, what they discussed, and to describe any additional supports they provided to coaches. Similarly, coaches were asked to describe their work with the principal and their views of how the principal supported their work. To understand the teachers' perceptions of the coach as someone who is capable of assisting them, teachers were

asked to describe if they worked with the coach and in what ways, as well as why they choose to work with the coach. In order to understand the structural aspects of the school, all participants were asked to describe whether teachers met as a group with the coach, how often, and the content of the meetings.

Measures of knowledge and practice as a teacher. As a means to examine the coaches' capabilities as mathematics teachers, we examined and scored two different types of data: 1) the *Learning Mathematics for Teaching* (LMT) assessment (Hill & Ball, 2004), and 2) video-recordings of two consecutive lessons for each of the coaches. These two measures (further explained in the following paragraph) enabled us to assess the coach's expertise, namely what they know and can do as mathematics teachers.

The first measure is a written assessment that measures the coaches' *mathematical knowledge for teaching* (MKT), which is one measure of the coach's expertise as a teacher. In March 2009, the research team assessed all participating teachers' and coaches' mathematics knowledge for teaching by using a pencil-and-paper instrument (composed of two subtests) developed by the Learning Mathematics for Teaching project that allowed for an estimation of both the coaches' and teachers' MKT, which is indicative of their understanding of mathematics content, students and student learning, and strategies for improving that learning (Hill & Ball, 2004).

A second measure of expertise is based on examinations of their teaching practices. Because the coaches in this district are half-time teachers and half-time coaches, we were able to videotape their instructional practices as middle school mathematics teachers. For each participant, we videotaped two consecutive lessons and used the *Instructional Quality Assessment* (IQA) (Matsumura, Slater, Junker, Peterson,

Boston, Steele, & Resnick, 2006) to assess the quality of their instruction. The instrument is consistent with District B's ambitious instructional visions. Because the protocol closely examines the type of tasks used and the discussion that takes place around the tasks, we explicitly asked participants to include a problem-solving activity and engage students in related whole class discussion in the lesson.

Data Analysis

Network survey. We began our analysis by examining the teachers' social networks in an attempt to characterize the coach centrality within each of the seven schools. We used UCINET social analysis software (Borgatti, Everett & Freeman, 2002) to create sociograms to begin to understand the extent the teachers' access the coach within each of the seven schools (see Appendix A). We asked all of the mathematics teachers within the school to fill out the network survey in order to get a clearer picture of the teacher network within the school; however, we were unable to get 100% participation from the additional teachers who were not a part of the full study. We first examined the response rate in the network survey and decided that in order to believe that we have a relatively accurate representation of the math teacher network in the school that it was important for over 60% of the teachers to respond, which left six schools (School 2-School 7) to examine.

To understand the centrality of the coach within the teacher networks, we utilized a measure of network centrality. Because of our interest in the influence of individuals within the teacher network, we chose to define centrality of an individual as the in-degree centrality, or the ratio of the number of ties directed toward that individual to the total ties

that could be directed toward that individual (Hanneman & Riddle, 2005). For example, if a school contains 6 mathematics teachers and a coach, and 4 of those teachers report that they seek advice from the coach then the in-degree centrality of the coach is $4/6$ or .6667. Using in-degree centrality, we calculated coach centrality in each of the seven schools. Based on each coach's in-degree centrality, we then grouped coaches into three categories of centrality: central, somewhat central, and not central.

Interviews. In order to document what influences the extent to which a coach is central in teachers' social networks, we coded all of the interview transcripts for the 32 teachers and their coaches and instructional leaders across the 7 schools. We created a coding scheme with categories that were developed from reviewing the literature on coaching and supporting teacher learning and from an initial reading of the interview transcripts (e.g., based on the questions that were asked and the participants' responses; see Appendix B). The coding scheme was designed to examine the conjectured influences through characterizing the following regarding coaches' work in the schools: 1) the expected role of the coach from all participants' perspectives, 2) the ways in which principals provide support to coaches, 3) activities in which the coach and principal co-participate, 4) why teachers indicate they go to the coach, and 5) structural aspects of the schools. We coded the interviews of teachers, coaches, and other instructional leaders (e.g., principals, assistant principals) in order to take into consideration different people's accounts of the role of the coach.

After coding all of the participants' interviews and considering coach centrality within teacher networks, we looked for patterns and variation within each of the 7 schools and across the schools regarding our conjectured influences and how they relate

to the extent to which a coach might appear as central to teacher networks in a school. For each of the 7 schools, we created analytic memos that described the patterns and variations specific to this focus. As part of these memos, we triangulated coaches', teachers', and instructional leaders' accounts of the coaches' work to ensure that we did not privilege any one person's account (i.e., we did not take just the coach's account of what she did with teachers but rather looked at her account against those of the teachers).

Measures of knowledge and practice as a teacher. We scored and analyzed the LMT assessments in order to understand each coach's mathematical knowledge for teaching. For each of two mathematical knowledge for teaching subtests, raw scores were translated into LMT-provided item response theory (IRT) scale scores, the determination of which was based on results from a pilot administration of the assessment to a national sample of approximately 640 practicing middle school teachers. For our analyses, we used a combined average of these two scale scores to form a single MKT score for each participant in each year.

In order to characterize each coach's instructional expertise, we used eight IQA rubrics⁷ that focus on the cognitive demand of the instructional tasks used in lessons and the nature of classroom discourse (Stein, et al., 2000), measuring the learning opportunities provided for students and, therefore, the effectiveness of instruction. Scores for each rubric range from 0 to 4, with a 0 representing a lack of the desired practice and a 4 representing high quality instruction. Each video was scored by coders trained in using the IQA rubrics. Coders were required to reach 80% reliability before beginning to code by themselves. After coding began, double-coding 20% of the

⁷ Potential of the Task, Task Implementation, Academic Rigor of the Discussion, Participation, Teacher Linking, Student Linking, Teacher Asking, and Student Providing. See (Boston & Wolf, 2006) for more information.

classroom sessions, with each rater being checked approximately every other week, assessed ongoing reliability. The overall percent agreement on those double-coded sessions was 73.5%. The percent of scores within one was 97.4%.

Selection of Cases

We used cross-case comparative analysis (Yin, 2003), for this study because we deliberately wanted to uncover contextual conditions of the school which we believe are highly pertinent to better understand how to better facilitate coaches' ability to support teachers' development of increasingly effective instructional practices. By comparing across schools, considering the setting and teachers' networks, we uncover some factors that appear to facilitate the teachers' use of the coach as someone to turn to for advice or information about mathematics and the coaches' ability to support those teachers. Our case selection began with our categorization of whether, within the schools, the coaches were central, somewhat central or not central to the teachers' network. We then closely examined the interview data for each of those schools.

Findings

Case Selection

Our primary criterion for case selection was coach in-degree centrality; information about coach centrality and other information used for case selection is provided in Table 1. As described above, based on their in-degree centrality, we categorized the coaches as central, somewhat central, and not central. We determined

that in 2 of the schools in which the coach was not central, it was because they were unable to fulfill their coaching responsibilities. In School 4, the coach's health was failing and did not allow her to work with teachers as intended. The coach in School 3 was asked by the principal to go back into the classroom to teach full time and therefore was unable to work with teachers during the school day. It was not surprising to find that the coaches in these schools were not central to teachers' networks, because they were not able to spend time working with teachers. This left four schools to compare in order to examine centrality of the coach within teachers' social networks (2 central: School 5, School 6, 1 somewhat central: School 7, and 1 not central: School 2).

School	# Math Teachers	# Teacher Responses	Response Rate	#Teacher-Coach Ties	In-degree centrality	Coach Centrality
1	12	4	33.3%	4	1	Central
2	9	6	66.7%	2	0.333	Not
3	20	14	70%	4	0.286	Not
4	12	8	66.7%	2	0.25	Not
5	14	9	64.3%	6	0.667	Central
6	6	6	100%	5	0.833	Central
7	7	7	100%	4	0.571	Somewhat

There is variation in centrality across the schools in our study, which we aim to account for by testing the following conjectured influences on centrality: (a) the expertise of the coach, (b) teachers' perceptions of the coach as someone who is capable of assisting them, (c) structural aspects of the school (e.g., time for groups of teachers to meet with the coach), and (d) the amount and type of support provided by the principal.

Expertise of the Coach

We conjectured that coaches with more expertise in teaching mathematics might be more central within teacher social networks because they have the potential to be a greater resource for teachers. In this study, we used two measures of expertise: mathematical knowledge for teaching (MKT; Hill, Schilling, & Ball, 2004) and the quality of their instructional practice (IQA; Boston & Wolf, 2006). Scores for individual coaches on each of these measures, described in greater detail above, are given in Table 2. We use MKT scores that are IRT scores based on a nationally representative sample (i.e., national mean=0, standard deviation = 1). The IQA scores are mean scores across the eight dimensions we assessed in our study. Recall that scores on the IQA range from 0 to 4, with a 0 representing a lack of the desired practice and a 4 representing high quality instruction. While there is some variation in the coach scores on these measures, there are not large enough differences to justify characterizing one coach as more expert than the others across both measures. As a consequence, we are unable to examine the influence of expertise on coach centrality within teachers' social networks. This does allow us to conclude that expertise is not the only factor that influences coach centrality, because while the coaches' expertise as measured by the LMT and IQA are similar, there were significant differences in their centrality. As we are unable to investigate the influence of expertise on coach centrality, this is an important area for future research. In particular, studies should investigate whether certain forms of expertise are more crucial for coach centrality, and how these forms of expertise influence the nature of interactions between coaches and teachers.

Table 2			
<i>Measures of Expertise for Mathematics Coaches</i>			
Coach	Centrality	LMT	IQA
School 6	Central	0.21	2.125
School 5	Central	0.47	2.25
School 7	Somewhat central	-0.35	2.75
School 2	Not central	-0.67	2.25

Teachers' Perceptions of Mathematics Coach

As stated previously, District B intended that coaches would assist all teachers in developing ambitious instructional practices. It is therefore important to consider why an individual teacher decided to go to the coach for advice or information about teaching mathematics. We conjectured that teachers' decisions to turn to a coach for advice would be influenced by their perceptions of the coach's expertise rather than by the coach's actual expertise per se. As we noted above, we were not able to examine the influence of coach expertise on coach centrality due to lack of variation in our measures of expertise. However, we were able to investigate the influence of teachers' perceptions of coach expertise by analyzing interview data for all of the participating middle grades mathematics teachers in District B (n=32). Rather than characterizing differences between schools where the coach was or was not central, instead we identify aspects of coaches' perceived expertise that teachers indicated were influenced their decisions to turn to the coach for advice about teaching mathematics. Those influences include: (a) the coach's years of experience, (b) their perceptions of the coach's knowledge of

teaching and the curriculum, (c) their perceptions of the coach's coaching ability, (d) their prior history of working with the coach.

Years of experience. The first perceived dimension of coach expertise indicated by approximately one-fourth of teachers was the number of years of experience teaching mathematics. For example, a teacher (at School 5) described the coach in the following terms: "She's kind of the master leader and because of her experience, twenty plus years, she has a lot of experience for us to draw on." Similarly, a teacher (at School 6) explained that he goes to his coach because "she's been teaching math here for a few years. She's, you know, she's got it [the mathematics curriculum] in her head." In most content-focused coach designs, the coach is intended to be a more knowledgeable other with regards to teaching a specific content (Coburn & Russell, 2008). Although years of experience is not necessarily a proxy for accomplishment as a teacher, some teachers view it as important that the coach can draw on extensive classroom experience to assist them.

Perceptions of the coach's knowledge. In addition to years of experience, teachers (approximately one-fourth) indicated that knowledge about teaching and the mathematics curriculum plays into their decision to go to the coach. For example, a teacher at School 6 explained that she seeks out the coach's advice because:

She has taught all three grade levels of math in middle school, so she knows what is taught at each grade level. Sometimes I have to ask her, 'Okay, should my Algebra kids already know this?' Because you know it is in the book, it is in the curriculum, yet they are clueless about this prior knowledge they are supposed to have, so I often will ask her questions referring to what's expected at other grade levels of the students.

As this teacher's explanation indicates, a coach's knowledge about teaching and history with the curriculum influence why some teachers choose to go to the coach.

Perceptions of coaching ability. The third influence on teachers' decisions to seek advice from the coach is their perceptions of the coaches' skills. This aspect of perceived coach expertise is related to the coach's competence to assist the teacher in improving his or her practice, the coach's competence as a teacher. Interestingly, teachers who sought advice from their coach and teachers who did not seek advice from their coach both mentioned this as an important criterion. Approximately one-fifth of teachers who identified their coach as someone they go to indicate they do so in part because of the coaches' abilities to communicate with and support them. For example, a teacher at School 5 indicated that he valued the manner in which the coach critiqued of his work: "Her constructive criticism is never taken, you know, with any animosity or anything. She's got a very easy way of working with people and she's not pushy." Another example is a teacher at School 6 who described the coach as someone who is "easy to get along with." A few teachers (about one-tenth) cited a lack of skills as a reason why they do not seek advice from the coach at their school. For example, one teacher at School 4 told us that she did not go to her coach because, "she thinks she is every single one of our bosses and that when she says jump, we must jump. And she's not easy to talk to."

Table 3					
<i>Years of Experience</i>					
School	Centrality	Years of Teaching (for coach)	Years Coaching	Years at School (for coach)	Average Years of Teaching (among teachers)
B6	Central	4	2	3	1
B5	Central	37	3	20	10.4
B7	Somewhat central	12	3	15	6.8
B2	Not central	28	3	1	1.75

Prior history. Another reason cited by approximately one-fourth of teachers interviewed for going to the coach was their prior history of working with the coach (i.e., the length of time they have worked together; prior collaboration). For example, a teacher at School 5 said, “I’ve been here for about fourteen years, and [the coach] was right across the hall from me when we, when I first started and she was my lifeline, you know. [When] I run into a problem, which was daily, you know, helping me or just, you know, keeping me going along the right path.” Similarly, other teachers (approximately one-fourth) indicated how that they received assistance from the coach in their first year of teaching and how they have continued to seek assistance from the coach in later years.

When a coach is new at a school, there are often consequences due to a lack of history. The coach at School 2 was in her first year at this school (see Table 4). However, she had taught for over 20 years and had been a coach for the previous 3 years in other schools in the district. She described how difficult it has been to come into School 2 and how she is still attempting to negotiate her role:

I think that once they know that I didn’t come to be the big bad wolf, I came to do a job the same as theirs and to be able to share anything that I might know that

would help them to be successful with their students and to learn from them anything that they may know how to do that I don't know. (Coach, School 2)

Her statement points to the importance of teachers' understanding of the role of the coach. We hypothesize that the coach needs to negotiate her role in order to build trust with teachers, which requires considerable interpersonal skills.

Summary. Our findings indicate that teachers' perceptions of the coaches' capabilities—as someone who can assist them and has knowledge about the curriculum, years of experience, and prior history—play into whether or not they decide to go to the coach for advice about mathematics. We now examine how school-level contexts influence coaches' centrality within teachers' social networks.

Structural Aspects of the School

We conjectured that coaches would be more central to teachers' social networks in schools where there was regularly scheduled time for teachers to meet with the coach as a group in order to work on issues of instruction. We analyzed interview data in order to examine this conjecture.

In all four schools, participants reported that time was allocated for mathematics teachers to meet with one another on a regular basis (see Table 4). At two schools (Schools 6 and 7), teachers met once a week, while they met more frequently at the other two schools (Schools 2 and 5). School 5, which serves only grades 7 and 8, had time allocated for same grade level teachers to meet with one another every other day, but they did not meet as a whole department. Teachers at the other schools (Schools 2, 6, and 7) met as a whole department (and also had other time for teachers to work with same-grade colleagues). There are differences in the frequency, length of time, and participants in

the meetings. However, these aspects do not appear to have had a direct impact on centrality. What does emerge as directly influential is the purpose and content of the meetings, and who led the meetings.

In the schools where the coaches were central within teachers' social networks, the teacher collaborative meetings focused on aspects of instructional practice. For example, a majority of teachers and the coaches in the two central schools reported that they did the following together: plan for upcoming instruction, do mathematics tasks from the curriculum together, consider possible solution strategies to mathematics tasks, discuss strategies for supporting different groups of students (e.g., ELL students), and discuss how past lessons played out with students. In both schools, the coaches both shaped and led the meeting agendas, which focused on key aspects of classroom instructional practice.

In contrast, the teachers and coaches reported doing the following activities at the two schools where the coaches were less central: discussing pacing (e.g., whether they were on pace with the district's curriculum frameworks), coordinating testing dates, and coordinating interventions or tutoring for individual students. In School 7, where the coach was somewhat central, the coach led the meetings but the content of the meetings did not focus on developing teachers' instructional practices (e.g., the meetings focused on identifying students who needed additional tutoring and negotiating who would lead the tutoring). In School 2, where the coach was not central, the department chair created the administratively focused agenda and led the meetings; the coach acted as a participant and did not take a leadership role. Our findings may therefore indicate the importance of the coach both leading the meetings and focusing the conversations on key aspects of

instruction. We hypothesize that routines for working together on instructional practice become established in such meetings and that it therefore becomes normal for teachers to talk to the coach about issues of instruction. Hence, teachers will be more likely to discuss instructional issues with the coach outside of formal teacher collaborative meetings, including as they debrief after the coach has observed a teacher's instructional practices.

Another initially conjectured influence on coach centrality was the size of the school. In District B's design, there are differences in the size of the schools and thus the number of mathematics teachers in each school (see Table 4). The difference in size influences the number of teachers a coach is expected to work with, as well as the amount of time the coach can spend with each teacher. Therefore, we expected that coaches would be more central in smaller schools, where they had fewer teachers to support. However, we found that the coach was central to teachers' social networks in both the smallest school (School 6) and the largest school (School 5) in our study. Hence, we conclude that school size does not directly influence centrality, if there is time built in for coaches to meet with teachers on a regular basis and work on issues of instruction.

We also found that teaching the same grade level as the coach was related to whether teachers sought advice from the coach. In all four schools, a majority (over 75%) of the teachers who taught the same grade as the coach indicated that they go to the coach for advice or information about mathematics instruction. Many teachers, who taught a different grade level than their coach, indicated that they turned to a same grade level colleague if they had a question about teaching mathematics before turning to the coach. In fact less than half of the teachers who taught a different grade level than the

coach (approximately 40%) identified the coach as someone they go to for advice about mathematics instruction. It would appear that teachers who teach the same grade level as the coach view the coach as a colleague who is grappling with similar curricular issues, which leads to their increased likelihood of seeking advice from them. It might well be the case that this influence is specific to coaching designs in which coaches teach a certain grade level for part of the day (e.g., 8th grade mathematics; see Table 4) and work with teachers for part of the day.

School	Centrality	# of Math teachers	Time to meet	Coach leads meetings?	Grades	Grade level coach teaches
2	Not Central	9	Every morning for 25 minutes as department (some of this time devoted to grade level)	No	6-8	8 th
5	Central	14	Every other day for an hour as grade level	Yes	7-8	7 th
6	Central	6	Once/week as department (additional time as grade level)	Yes	6-8	8 th
7	Somewhat Central	7	Once/week as department (additional time as grade level)	Yes	6-8	8 th

Principal Support for the Mathematics Coach

As explained previously, prior studies indicate that coach effectiveness depends on school leaders supporting coaches in their work (Matsumura et al., 2009). We analyzed interview data in order to determine whether principals' practices as instructional leaders and their interactions with coaches influence whether the coach is

central within teachers' social networks. In schools where the coaches were central, we identified a set of principal leadership practices that appear to support the coaches' work with teachers. These practices are: (a) attending teacher collaborative meetings; (b) observing teachers' classroom instruction; and (c) meeting with the coach one-on-one weekly to identify teachers with whom the coach should work, and to discuss how to work with those teachers. An additional finding that emerged is that the principals in the schools where the coach was more central were able to articulate concrete expectations for how coaches should work with teachers that were compatible with district leaders' expectations.

Attending teacher collaborative meetings. The first finding is that in the schools where the coaches were central, principals attended the teacher collaborative meetings regularly. In the school where the coach was not central, the attendance of the principal was much more infrequent. In particular, at School 2 (where the coach is not central), teachers reported that the principal "pops in" to the meetings in order to discuss upcoming dates or information regarding different state or district policies (e.g., modifications for state testing). The principals at the other schools, where the coaches were more central, attended department meetings on a regular basis and stayed for the entire meeting. However, our data suggests that the principals' purposes for attending the meetings differ, and therefore might influence centrality.

As described previously, at the school where the coach is not central (School 2), the principal describes the purpose for his visits as primarily administrative. This differs from the purposes described by the principals in the two central schools. The principals at the two central schools both described that they attend teacher collaborative meetings

for reasons broadly related to setting expectations about teachers' instructional practices. For example, in School 5, the principal described how he holds both the coach and teachers accountable for working on issues of instruction during the collaborative time. He then uses this time to assess teachers' current understandings of instruction (e.g., he listens to how teachers are discussing instruction). The principal at School 6 described how she used the department meetings to tell teachers what she is looking for when she observes a lesson and, after conducting observations, shares her assessments of what took place when she observed a classroom.

We hypothesize that in addition to using the meetings to communicate expectations for teachers, principals might improve their understanding of middle grades mathematics instruction. When meetings are led by the coach and focused on instructional issues, principals can benefit from participating in these meetings and come to better understand the mathematics underlying key instructional tasks and key pedagogical practices used to support students' learning. Also, because principals at the central schools observe coaches' direct interactions with teachers during teacher collaborative time, this might support the principals' ability to develop expectations for coaches' work with teachers, which is described in more detail in the following section.

Observation of classroom instruction. Another key finding is that principals in the schools in which the coaches are more central (Schools 5, 6, and 7) visited classrooms on a regular basis to observe teachers' instruction and provide teachers feedback. Evidence that principals observed instruction was based on both teachers' and principals' interviews. In the smaller schools (Schools 6 and 7, see Table 3), the principals reported observing teachers on a daily basis. In School 5, a larger school, the principal reported

setting aside one day each week to observe mathematics instruction. On the other hand, in the school where the coach is not central (School 2), the principal did not regularly observe teachers' instruction.

Because the principals in the schools where the coach is central spend considerable time in both teachers' classrooms and collaborative meetings, where teachers are working on and discussing their instructional practices, principals can have a better understanding of the demands of the curriculum being taught and the aspects of pedagogy the teachers were working on. It appears that principals then could better press and hold teachers accountable for developing the intended instructional practices (Elmore, 2006; Printy & Marks, 2006; Spillane, Halverson & Diamond, 2004).

Principal and coach meetings. As described earlier, principals in District B were required to meet with their content-focused coaches in a weekly cross-disciplinary leadership meeting in order to discuss school-wide improvement (e.g., important dates in the school calendar, schedule testing, discuss content of school-based professional development days). These meetings took place across all four schools. Although there was discussion about instructional issues generally in addition to administrative issues, often there was not time in these meetings to talk specifically about mathematics or about individual teachers' needs.

Another key finding is that in the three schools where the coaches were more central (Schools 5, 6, and 7), the principals explicitly set aside additional time outside of the formal leadership meetings to talk with their mathematics coaches one-on-one. For example, the principal at School 7 (somewhat central) indicated that he meets with each of the content-focused coaches individually, "I'll have my coaches come back in and

that's when we have a real focused, where are you at? You know, those things we can't talk about in front of everybody. They give me concerns...they're in here all the time and so we're constantly communicating." In the not central school (School 2), the principal and coach do not report meeting together regularly to discuss supporting individual teachers. Evidence that these one-on-one meetings, and the content of the meetings took place was based on both principals' and coaches' accounts.

The principals and coaches who meet on a regular basis appear to mutually assist each other by discussing how to provide support for teachers. Because these same principals also spent time in classrooms, they were also able to suggest which teachers the coach should work with and discuss specific supports for particular teachers. These types of discussions allow the principal and the coach to negotiate how they will support instructional improvement in their school and orchestrate how they will each provide that assistance.

Expectations of the coach. An additional finding that emerged is that all of the principals described the role of the coach as one of supporting teachers; however, the principals in the schools where the coach was more central were able to articulate concretely how the coach is to assist teachers, which was consistent with district leaders' expectations. In the two schools where the coach was central, the principals both described the following ways in which the coach should assist teachers: give teachers methods and tools to help them be successful in their classrooms, provide assistance through one-on-one coaching (e.g., model lessons with the teachers who might need assistance), work on instructional issues with teachers as a group, and mentor teachers. In contrast, in the less central schools, the principals were more vague when describing

the role of the coach, saying that coaches should “go into classrooms and help teachers head in the right direction” (Principal, School 7) and “monitor and address teacher issues” (Assistant Principal in charge of mathematics instruction, School 2). In these less central schools, the principals described the role more generically as helping to orient the weak teachers on the right path, with very little specific description of how the coach was to work with the teachers. We hypothesize that the principals at the central schools were able to articulate more concretely the ways in which coaches should support teachers because they worked more closely with their coaches. Specifically, they attended math department meetings on a regular basis and met with the coach individually to discuss instruction on an ongoing basis.

Furthermore, even though the principals described the role of the coach as primarily supporting teachers, all of the coaches indicated that their principals expected them to do additional duties. These additional duties appear to be a barrier to centrality because they reduced the time that the coaches could spend directly supporting teachers. For example, one of the coaches excluded from the analysis was the coach at School 3. Recall that she was excluded because she was asked by the principal to return to the classroom and teach full time, which meant that she was left with little time to support teachers.

One common additional duty across all four schools in the analysis is related to high-stakes testing. At all of the schools, there was a focus on raising achievement on the state test, though to varying degrees. All coaches described spending time analyzing district benchmark data on a regular basis in order to assist teachers in deciding which concepts need to be retaught. Coaches also analyzed these data to identify which

students needed tutoring for which content. The coaches described the extensive tutoring programs at each of their schools and reported that they spend a considerable amount of time running the programs, especially during the second half of the school year. These extra duties of preparing for benchmark assessments, compiling data, and planning for tutoring were not in accord with the design of the coaching program and may have limited the coach's accessibility to the teachers.

It is possible that principals might have assigned these additional duties because they did not have a deep understanding of ambitious teaching, the complexity of this type of instruction, and the amount of support teachers need to develop instructional practices of this type. The response to high-stakes testing and a lack of understanding of ambitious teaching on the part of the principal is likely to extend beyond the principals in this study (see for example, Burch & Spillane, 2003; Elmore, 2000; Fink & Resnick, 2001).

Without an appreciation for the amount of support teachers need to develop these types of practices, principals cannot fully appreciate the importance of the coaches' work with teachers and therefore, are unlikely to find other personnel to attend to tasks dealing with administering tests and tutoring.

In sum, our examination of interview data suggests that in the schools in which the coach is more central, principals and coaches took joint responsibility for instructional improvement. Principals assisted the coach more directly and were able to help select the teachers with whom the coach should work, in large part because the principal observed the teachers' instructional practices and participated in mathematics department meetings regularly. Based on our findings, we hypothesize that as principals spend time in mathematics department meetings developing their understandings of high

quality instructional practices, they can observe classroom instruction and provide feedback that will press for these high quality practices, suggest that the teacher work with the coach on a specific aspect of practice, and discuss what they have observed with the coach who can provide assistance specific to that teacher's needs. This will also support principals' understanding of the demands of ambitious teaching and the amount of support teachers need to develop these forms of practice.

Discussion

In this study, we investigated what influences the extent to which mathematics coaches are central within teachers' social networks. This analysis suggests that teachers' perceptions of the coach's competence, specific structural aspects of the school setting and principal support can influence whether a majority of teachers within a school go to their coach for advice or information about teaching mathematics.

Due to a lack of variation among coaches on our measures of mathematical knowledge for teaching and instructional quality, we were unable to determine whether coaches' instructional expertise was related to coach centrality. However, we did examine teachers' perceptions of coaches' competence, as well as prior history and interpersonal contact. Prior studies have shown that teachers seek out advice from others because of proximity and prior history (Coburn & Russell, 2008). Similarly, this study found that teachers indicated prior history as a reason they turned to the coach for advice or information about teaching mathematics. Additionally, we found that teachers cited coaches' years of experience and their coaching skills as reasons for why they go to the coach. Finally, we learned that teachers' perceptions of coaches' knowledge of teaching

and the curriculum came into play when deciding whether to go to the coach for advice or information.

We found that time for groups of teachers to work together did not, itself, influence the extent to which coaches were central within teachers' social networks, but that characteristics of that meeting time did influence the extent to which coaches were central. The principals in schools where the coaches were central structured time for coaches to meet with teachers and pressed them to work in meaningful ways on instructional issues. When the coach led these meetings and guided teachers in working on issues of instruction (e.g., discussing possible solution strategies to mathematics tasks), teachers were more likely to identify the coach as someone they turned to for advice or information about instruction.

Several studies have indicated that content-focused coaches require the support and backing of school principals to effectively perform their responsibilities (Grant & Davenport, 2009; Matsumura et al., 2009; Mangin, 2005, 2007; Smylie, Conley & Marks, 2002; Youngs & King, 2002; Marks & Printy, 2003). Our work builds on prior studies by identifying a set of concrete practices that principals can carry out within their schools in order to support coaches in becoming a central source of expertise. Our findings suggest the importance of both the principals' indirect support of the coach through interactions with teachers, while also building on the current literature, which has identified the importance of principals' direct support for coaches.

We also found that schools in which the coaches were more central had principals who regularly attended teacher collaborative meetings and observed classroom instruction. In addition, the principals set aside time to meet with the mathematics coach

individually to discuss the progress teachers were making on developing high quality instructional practices. These principals were concerned with working alongside coaches to bring about instructional improvement. The principals and coaches in the more central schools shared responsibility for supporting teachers in enacting high quality instruction.

This analysis has several implications for district leaders as they implement and refine content-focused coaching designs. First, it has implications for the role and responsibilities of the coach. Our findings raise the issue that careful attention needs to be paid to what coaches are asked to do. We found that an important part of coaches' work is to lead regular teacher collaborative meetings that focus on issues of instruction. We hypothesize that routines for working together on instructional practice become established in such meetings. It then becomes customary for teachers to talk to the coach about matters of instruction outside the formal teacher collaborative meetings. One implication for principals, therefore, is to hold both the coach and the teachers accountable for focusing on matters of instruction during this time.

Another implication related to the role and responsibilities of the coach is for the principal to come to appreciate the importance of the coach's work, thereby protecting their time to be spent solely on supporting teachers' development of ambitious instruction. This closely relates to principal professional development and assisting principals to develop sophisticated understandings of what ambitious teaching entails. If principals come to understand high quality mathematics instruction and appreciate how difficult it is to implement, they then can acknowledge the amount of support that teachers need to develop these types of practices.

Second, there are implications for the role and responsibilities of the principal. We found that in schools where coaches were more central within teachers' social networks, principals provided both direct and indirect support to those coaches. Based on our findings, we hypothesize that as principals spend time in mathematics department meetings further developing their understandings of high quality instructional practices, they can observe classroom instruction and provide feedback that will press for these high quality practices. In conjunction with the feedback, principals can also suggest that the teacher work with the coach on a specific aspect of practice. After observing instruction, principals can meet with content-focused coaches and discuss what each has observed in teachers' classrooms. Together they can decide what type of assistance a particular teacher needs from the coach, as well as plan the content for upcoming teacher collaborative meetings based on an assessment of teachers' current instructional practices. However, we recognize that these conversations are sensitive and can create tension between the coach's role as a supporter and not evaluator. Principals need to be held accountable by district leaders for attending teacher collaborative meetings, observing classroom instruction and providing feedback that presses teachers to develop ambitious practices, and meet regularly with the mathematics coach in order to mutually assist each other by discussing how to provide support for teachers.

This study suggests several directions for future research. As Coburn and Russell (2008) suggested, the creation of the coaching role alone does not increase teachers' access to expertise. While understanding what influences whether coaches become a central resource for teachers, we acknowledge that the content of the coaches' and teachers' interactions and the activities in which they co-participate is an important

next step in understanding how coaches support teachers. Interactions that are of sufficient depth that are close to practice are likely to support teachers to reorganize their current practices and develop ambitious instructional practices (Cobb & Smith, 2008; Borko, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Wilson & Berne, 1999). It is important to identify what types of activities (e.g., co-teaching) that coaches and teachers can co-participate in, which will lead to changes in teachers' practices, as well as understand what influences coaches to engage in these types of activities with teachers. By doing so, we will extend our understanding of how coaches can be supported to assist teachers to reorganize their instructional practices in order to provide improved opportunities for student learning.

References

- Ball, D. L., Hill, H. H., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, Fall, 14-46.
- Borgatti, S.P., Everett, M.G. and Freeman, L.C. 2002. Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Boston. M. D., & Wolf, M. K. (2006). *Assessing academic rigor in mathematics instruction: The development of Instructional Quality Assessment Toolkit*. National Center for Research on Evaluation, Standards, and Student Testing (CRESST) Report #672.
- Bradley, J. A. T. (2007). *Exploring an alignment focused coaching model of mathematics professional development: content of coach/teacher talk during planning and analyzing lessons*. University of Texas at Austin, Austin, TX.
- Bryk, A., Sebring, P. B., Allensworth, E., Leppescu, S., Easton, J. Q. (2010). *Organizing Schools for Improvement: Lessons from Chicago*. Chicago, IL: University of Chicago Press.
- Bryk, A. S., & Schneider, B. (2002). *Trust in schools: A core resource for improvement*. New York: Russell Sage Foundation.
- Burch, P., & Spillane, J.P. (2003). Elementary school leadership strategies and subject matter: Reforming mathematics and literacy instruction. *Elementary School Journal*, 103(5), 519-535.
- Campbell, P. D., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal* 111(3), 430-454.
- Cantrell, S. C., & Hughes, H. K. (2008). Teacher efficacy and content literacy implementation: An exploration of the effects of extended professional development with coaching. *Journal of Literacy Research*, 40, 95-127.
- Cobb, P., & Smith, T. (2008). The challenge of scale: Designing schools and districts as learning organizations for instructional improvement in mathematics. In T. Wood, B. Jaworski, K. Krainer, P. Sullivan & D. Tirosh (Eds.), *International handbook of mathematics teacher education*. Rotterdam, Netherlands: Sense.

- Coburn, C. E. (2001). Collective sensemaking about reading: How teachers mediate reading policy in their professional communities. *Educational Evaluation and Policy Analysis*, 23(2), 145–170.
- Coburn, C. E. (2006). Framing the problem of reading instruction: Using frame analysis to uncover the microprocesses of policy implementation in schools. *American Educational Research Journal*, 43(3), 343-379.
- Coburn, C. E. & Stein, M. K. (2006). Communities of practice theory and the role of teacher professional community in policy implementation. In M. Honig, (Ed.), *Confronting complexity: Defining the field of education policy implementation* (pp. 25-46). Albany: SUNY Press.
- Coburn, C. E., & Russell, J. L. (2008). District Policy and Teachers' Social Networks. *Educational Evaluation and Policy Analysis*, 30(3), 203-235.
- Coleman, J. S. (1990). *Foundations of social theory*. Cambridge: Harvard University Press.
- Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Palo Alto, CA: Stanford University and National Council of Staff Development.
- Elmore, R. F., Peterson, P., & McCarthey, S. (1996). *Restructuring in the classroom: Teaching, learning, and school organization*. San Francisco: Jossey-Bass.
- Elmore, R. F. (2000). *Building a new structure for school leadership*. Albert Shanker Institute.
- Fink, E., & Resnick, L.B. (2001). Developing principals as instructional leaders. *Phi Delta Kappan*, 82, 578-606.
- Frank, K. A., Zhao, Y., & Borman, K. (2004). Social capital and the diffusion of innovations within organizations: The case of computer technology in schools. *Sociology of Education*, 77(2).
- Franke, M. L., & Kazemi, E. (2001). Learning to teach mathematics: Developing a focus on students' mathematical thinking. *Theory Into Practice*, 40, 102-109.
- Gamse, B. C., Jacob, R. T., Horst, M., Boulay, B., & Unlu, F. (2008). *Reading First impact study final report* (NCEE 2009-4038). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

- Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4).
- Gibbons, L. K. (2011). Examining what influences the types of activities in which mathematics coaches engage teachers. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Grant, C. M., & Davenport, L. R. (2009). Principals in partnership with math coaches. *Principal*, 36-41.
- Hanneman, R. A. & Riddle, M. (2005). *Introduction to social network methods*. Riverside, CA: University of California, Riverside (published in digital form at <http://faculty.ucr.edu/~hanneman/>)
- Hill, H. C. & Ball, D. L. (2004) Learning mathematics for teaching: Results from California's mathematics professional development institutes. *Journal of Research in Mathematics Education*, 35, 330-351.
- Hill, H. C., Schilling, S. G., & Ball, D. L. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, 39(4), 372-400.
- Horn, I. S., & Little, J. W. (2010). Attending to problems of practice: Routines and resources for professional learning in teachers' workplace interactions. *American Educational Research Journal*, 47(1), 181-217.
- Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, 7, 203-235.
- Lappan, G., Fey, J. T., Fitzgerald, W. M., Friel, S. N., & Phillips, E. D. (2009). *Connected Mathematics Project 2*. Boston: Pearson.
- Little, J. W. (1982). Norms of collegiality and experimentation: Workplace conditions of school success. *American Educational Research Journal*, 19(3), 325-240.
- Lin, N. (2001). *Social capital: A theory of social structure and action*. New York: Cambridge University Press.
- Louis, K. S., & Kruse, S. D. (1995). *Professionalism and Community: Perspectives on Reforming Urban Schools*. Thousand Oaks, CA: Corwin Press.
- Louis, K. S., Marks, H. M., & Kruse, S. (1996). Teachers' Professional Community in Restructuring Schools. *American Educational Research Journal*, 33, 757-798.

- Mangin, M. M. (2005). Teacher leadership and instructional improvement: Teachers' perspectives. In W. K. Hoy & C. Miskel (Eds.), *Contemporary issues in educational policy and school outcomes* (pp. 159-192). Greenwich, CT: Information Age Publishing.
- Mangin, M. M. (2007). Facilitating Elementary Principals' Support for Instructional Teacher Leadership. *Educational Administration Quarterly*, 43(3), 319-357.
- Marks, H. M., & Printy, S. M. (2003). Principal leadership and school performance: An integration of transformational and instructional leadership. *Educational Administration Quarterly*, 39(3), 370-397.
- Marsh, J., McCombs, J., Lockwood, J. R., Martorell, F., Gershwin, D., Naftel, S., Le, V., Shea, M., Barney, H., & Crego, A. (2008). Supporting literacy across the sunshine state: A study of Florida middle school reading coaches. Santa Monica, CA: Rand Corporation. http://www.rand.org/pubs/research_briefs/RB9374/
- Matsumura, L. C., Slater, S. C., Junker, B., Peterson, M., Boston, M., Steele, M., & Resnick, L. (2006). Measuring reading comprehension and mathematics instruction in urban middle schools: a pilot study of the instructional quality assessment. National Center for Research on Evaluation, Standards, and Student Testing (CRESST) Report #681.
- Matsumura, L. C., Sartoris, M., Bickel, D. D., & Garnier, H. E. (2009). Leadership for literacy coaching: The principal's role in launching a new coaching program. *Educational Administration Quarterly* 45(5) 655-693.
- Matsumura, L. C., Garnier, H. E., Resnick, L. (2010). Implementing literacy coaching: The role of school social resources. *Educational Evaluation and Policy Analysis*, 32(2), 249-272.
- McLaughlin, M. W., & Talbert, J. E. (2006). *Building school-based teacher learning communities: Professional strategies to improve student achievement*. New York: Teachers College Press.
- Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity, promises and practicalities*. Washington, DC: Aspen Institute Program on Education and Annenberg Institute for School Reform.
- Penuel, W. R., Riel, M., Krause, A. E., & Frank, K. A. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record*, 111(1), 124-163.
- Poglinco, S. M., Bach, A., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003). *The heart of the matter: The coaching model in America's Choice schools*.

Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.

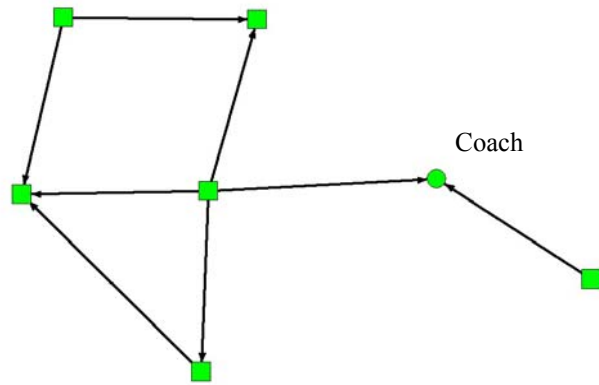
- Portes, A. (1998). Social capital: Its origins and applications in modern sociology. *Annual Review of Sociology*, 24, 1-24.
- Printy, S. M., & Marks, H. M. (2006). Shared leadership for teacher and student learning. *Theory Into Practice*, 45, 125-132.
- Ross, J. (1992). Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education*, 17(1), 51-63.
- Sailors, M. & Price, L. (2010). Professional development that supports the teaching of cognitive reading strategy instruction. *The Elementary Journal*, 110(2), 301-322.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Shulman, L. S. (1987). Knowledge and teaching. *Harvard Educational Review*, 57, 1-22.
- Smylie, M. A., Conley, & Marks, H. M. (2002). Exploring new approaches to teacher leadership for school improvement. In J. Murphy (Ed.), *The educational leadership challenge: Redefining leadership for the 21st century; 101st yearbook of the National Society for the Study of Education* (Vol. 101, pp. 162-188). Chicago: University of Chicago Press.
- Spillane, J. P., Reiser, B., & Gomez, L. M. (2006). Policy implementation and cognition: The role of human, social, and distributed cognition in framing policy implementation. In M. I. Honig (Ed.), *New directions in educational policy implementation* (pp. 47-64). Albany, NY: State University of New York Press.
- Spillane, J. P., Halverson, R., & Diamond, J. B. (2001). Investigating school leadership practice: A distributed perspective. *Educational Researcher*, 30(3), 23-28.
- Van Keer, H., & Verhaeghe, J. P. (2005). Comparing two teacher development programs for innovating reading comprehension instruction with regard to teachers' experiences and student outcomes. *Teacher and Teacher Education*, 21, 543-562.
- Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 173-209). Washington, DC: American Educational Research Association.
- Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Youngs, P., & King, M. B. (2002). Principal leadership for professional development to build school capacity. *Educational Administration Quarterly*, 38(5), 643-670.

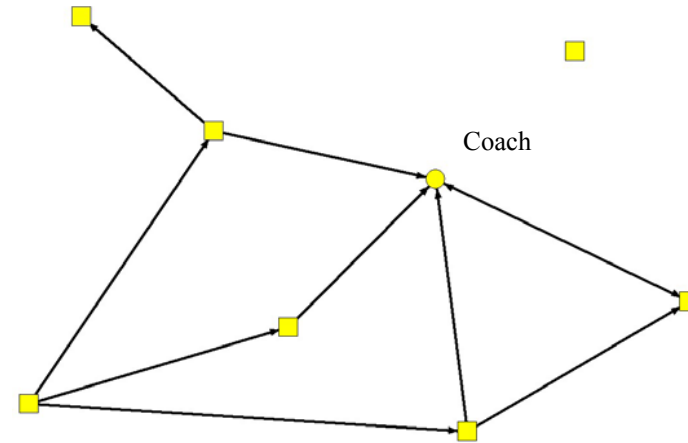
Appendix A

Figure 1. School sociograms of mathematics teacher networks [Square nodes are teachers and circular nodes are coaches. The arrows indicate the direction of the advice-seeking relationship.]

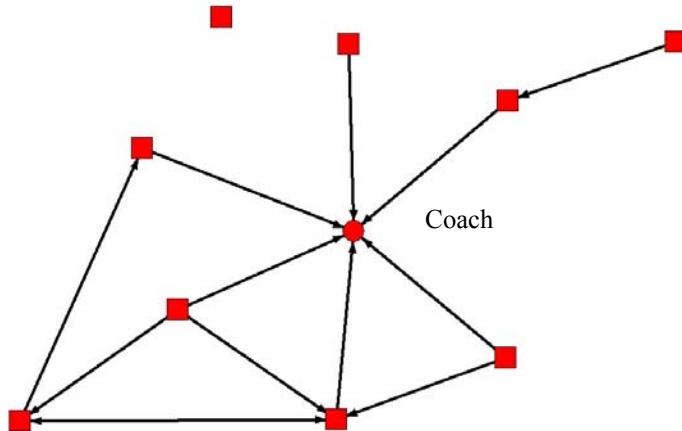
School 2- Not central coach



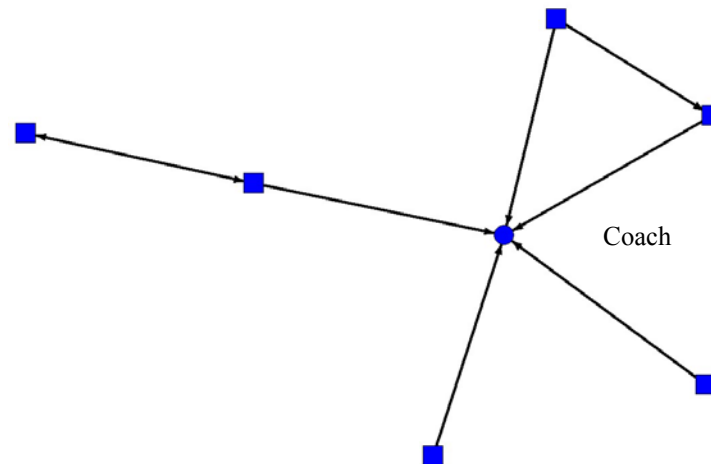
School 7-Somewhat central coach



School 5-Central coach



School 6-Central coach



Appendix B

Coding Scheme for Analysis of Interview Data

The following pages contain the parts of the coding scheme that were used to code interview data for this study. The coding scheme was created with categories that were developed from reviewing the literature on coaching and supporting teacher learning and from an initial reading of the interview transcripts (e.g., based on the questions that were asked and the participants' responses).

The software that I used to code the interview data is NVivo9. The codes were created in NVivo and exported into a table to display here; the first four columns of the table below were copied directly from NVivo. The table contains the five parent nodes used for this analysis, and the corresponding child nodes. The column on the right contains definitions for each of the nodes.

Parent Node	Child Node	Child Node	Child Node	Definition of code
0 Coach Personal				About the coach
	0.1 History			History
		0.1.1 Before Coaching		"What did you do before you became a coach? Where?"
		0.1.2 How long coaching		"How long have you been working as a coach?"
	0.2 C reaction to transition			"How difficult was it to transition from a teacher to a coach?"
	0.3 Hiring			"Who hired you for this position? What was the process?"
	0.4 C goals			Coaches goal for working with teachers
	0.5 C Challenges			What are some major challenges that you have experienced in supporting teachers' learning?
	0.6 C on effective ways to support T			"What do you think are effective ways to support math teachers in improving their classroom practice?"
1 Aspects of Institutional Setting				
	1.1 Time existence			Time exists to meet formally
		1.1.1 Math Department Formal Meetings		Formal math department/grade level meetings
			1.1.1.1 C leads	Coach formally leads math department meetings
			1.1.1.2 C does	Coach does not indicate leading the meetings/descriptions of

			not lead	department meetings
		1.1.2 Common Planning		Math teachers meet with other teachers in the same grade level
		1.1.3 Time not allotted		Time is not allotted for teachers to meet with one another during the school day
	1.2 Coach PD			
		1.2.1 CMP MI training		Coach attended CMP2 training with curriculum designers at Michigan State
		1.2.10 Culturally Responsive Classroom		Coach Indicates receiving culturally responsive classroom training
		1.2.11 No Coach PD		Coach reports not receiving PD
		1.2.2 CMP, district		Coach attended CMP2 training with curriculum experts in district OR district focuses on CMP in training
		1.2.3 IFL (DL, Pitt)		Coach attended IFL in Pittsburgh; or in district
		1.2.4 Combined CMP and IFL		Training is combined CMP and IFL
		1.2.5 How to analyze data		Coach received training on how to analyze data
		1.2.6 Cognitive Coaching		Coach receives training on 'cognitive coaching'
		1.2.9 Other, Coaching training		Coach receives other types of training pertaining to coaching
		1.2.8 Other, Content training		Coach receives other training on mathematics content
		1.2.7 ELL_LEP training		Training received around ELL (e.g., sheltered instruction SIOP)
	1.4 School-based_principal support			Support from principal

		1.4.1 Access to Materials		Coach is given resources to do her work
		1.4.2 Access to Space for Coach		Coach has space to do her work
		1.4.3 Access to Classroom		Coach has time and teacher allows access to the classroom
		1.4.4 Other		
	1.3 Coach networks			Coach is able to meet/talk with other coaches (includes content of conversations)
2 Legitimacy				
	2.3 C Traits			Interpersonal Skills
		2.3.1 Supportive_non-evaluative		The coach is supportive of teachers
		2.3.2 Communication		Why a teacher goes to a coach around communication (e.g., good listener)
		2.3.3 Other		
	2.4 Perception of expertise			What the coach knows
		2.4.1 Knowledge of Curriculum		Teachers go to coach because they think the coach possesses some expertise in curriculum
		2.4.2 Knowledge of ClassManag_Rel with S		Teachers go to coach because they think the coach possesses some expertise in classroom management (e.g., discipline)
		2.4.3 Knowledge of Students		Teachers go to coach because they think coach has knowledge about these types of students (e.g., middle school, how kids learn, ELLs, etc...)
		2.4.4 Knowledge of		Teacher goes to coach because they think coach possess

		Mathematics Content_PCK		knowledge about math content
		2.4.5 Other		
	2.5 T response to C			
		2.5.1 Positive		Teacher feels grateful towards coach; Teacher indicates the coach is influential in his/her teaching
		2.5.2 Negative		Teacher does not feel supported by the coach
		2.5.3 Neutral		Teacher feels neutral about the coach
3				
Communication Alignment				Communication about the coach role
	3.1 Communication to T			Communication about the coach role to teachers
	3.2 Communication to Coach			Communication about the coach role to coaches
		3.2.1 D and P conflict		Coach reports District and principal conflict in messages to coach
		3.2.2 D and P consistent		Coach reports District and Principal give the same messages
	3.3 Communication to P about C			Communication to principal (e.g., from district) about the role of the coach
6 Other C duties				Additional duties/Time spent outside of directly assisting teachers
	6.1 C align assessments with state standards			Coach aligns assessment with state standards

	6.10 C covers T class			Coach substitutes for class
	6.11 C scheduling			Coach schedules students to classes/coach helps with master schedule
	6.12 C and TL collaborate together			Coach collaborates with other teacher leaders
	6.13 Other			Other
	6.2 C oversees tutoring_math camps_Saturday school for S			Coach oversees tutoring program (e.g., before/after school tutoring, tutoring camps, Saturday school)
	6.3 C gathers testing materials			Coach gathers/distributes/collects testing materials
	6.4 C analyzes test scores			Coach analyzes student test scores (without teachers present)
	6.5 C tutors S			Coach tutors students
	6.6 C writes curriculum/pacing guides			Coach writes curriculum or creates pacing guides
	6.7 C conducts district PD			Coach conducts district PD
	6.9 C serves as department chair			Coach serves as department chair

CHAPTER IV

EXAMINING PROFESSIONAL VISION FOR COACHING AND RELATED PRACTICES

Introduction

Across the United States, many school districts are directing significant funds to content-focused coaching as a primary strategy for providing professional development for teachers (Coburn & Russell, 2008; Darling-Hammond, Wei, Andree, Richardson & Orphanos, 2009; McLaughlin & Talbert, 2006; Neufeld & Roper, 2003; Poglinco, Bach, Hovde, Rosenblum, Saunders & Supovitz, 2003). This type of coaching is intended to provide on-site, job embedded professional development in which teachers work with a more accomplished colleague—a coach (West & Staub, 2003). Theoretically, content-focused coaching is a potentially promising approach for supporting teachers' learning because the activities in which teachers engage with coaches can be directly relevant to the teachers' classroom practices (Coburn & Russell, 2008; Neufeld & Roper, 2003; Poglinco, et al., 2003). The findings of a number of recent studies indicate that teachers' co-participation with an accomplished colleague in activities of sufficient depth that are close to practice can support their development of ambitious practices (Borko, 2004; Frank, Zhao & Borman, 2004; Franke & Kazemi, 2001; Kazemi & Franke, 2004; Penuel, Riel, Krause & Frank, 2009; Wilson & Berne, 1999).

Research on content-focused coaching has examined aspects of the school and district context that support coaches to work with teachers and influence coach effectiveness (Campbell & Malkus, 2011; Cantrell & Hughes, 2008; Coburn & Russell,

2008; Gamse, Jacob, Horst, Boulay, & Unlu, 2008; Mangin, 2005, 2007; Matsumura, Sartoris, Bickel, & Garnier, 2009; Ross, 1992; Sailors & Price, 2010; VanKeer & Verhaeghe, 2005). However, few studies have investigated what coaches need to know and be able to do in order to support teachers effectively. Policy makers and district leaders are making consequential decisions about coaching with only limited guidance from the research. As a consequence, district leaders have to rely on their best judgment when considering who to hire and how to support them in becoming effective coaches. Therefore, research is needed that clarifies the expertise needed to enact coaching practices and thus delineates goals for coaches' learning and professional development.

This exploratory study investigates what, in addition to being relatively accomplished teachers, mathematics coaches need to know and be able to do in order to engage teachers in activities that are likely to support their development of high quality instructional practices. The data for this analysis comes from a longitudinal study⁸ that examines what it takes to support mathematics teachers' development of ambitious and equitable instructional practices at scale. This study focuses on one school-based middle-grades mathematics coach who consistently engaged teachers in productive activities.

I begin the report of this study by discussing the mathematics education research community's delineation of learning goals for students and a set of instructional practices that support students' achievement of those goals. Next, I provide a review of the existing content-focused coaching literature. Finally, through the analysis of interview data, I examine key aspects of knowledge and practice that result in engaging teachers in

⁸ The Designing Learning Organizations for Instructional Improvement in Mathematics Study is funded by the NSF, award No. ESI 0554535. Paul Cobb (Co-PI), Tom Smith (Co-PI), Erin Henrick (Project Manager), Glenn Colby, Annie Garrison, Lynsey Gibbons, Kara Jackson, Karin Katterfeld, Chuck Munter, Rebecca Schmidt, Jonee Wilson

activities that are likely to support their development. This analysis suggests three important aspects of coaching knowledge, or what I call *professional vision for coaching*, which comprises: (a) long-term goals for teachers' development, (b) initial trajectories of teachers' development, and (c) a repertoire of learning activities. In addition, analysis suggests an associated set of coaching practices, which include: (a) assessing teachers' current instructional practices, (b) identifying next steps for teachers' development, and (c) selecting from a repertoire of learning activities.

Supporting Teachers' Development of Ambitious Practices

The goal of content-focused coaching is to support teachers' development of high quality instructional practices. In order to understand what counts as high quality teaching, we must consider teaching in relation to goals for students' learning. Over the past two decades, researchers in mathematics education have come to a broad consensus on a set of goals for students' learning that focuses on understanding central mathematical ideas (Kilpatrick, Swafford & Findell, 2001; Lappan, 1997; National Council of Teachers of Mathematics (NCTM), 2000; U.S. Department of Education, 2008). These goals emphasize: (a) developing both conceptual understanding and procedural fluency in a range of mathematical domains, (b) using and making connections between multiple representations, (c) creating increasingly sophisticated mathematical arguments in order to communicate and justify mathematical reasoning effectively, and (d) developing a productive disposition towards mathematics. These goals for students' learning have led to new conceptions of teachers' work that has been

referred to as *ambitious teaching* (Lampert, Beasley, Ghouseini, Kazemi, & Franke, 2010; Lampert & Grieziani, 2009).

Recent research in mathematics education has delineated a set of instructional practices that constitutes ambitious instruction in which teachers to teach in response to what students do as they attempt to solve challenging tasks (Franke, Kazemi & Battey, 2007; Hiebert, Carpenter, Fennema, Fuson, Wearne, & Murray, 1997; Kazemi, Franke, & Lampert, 2009; NCTM, 2000). These practices include supporting students to solve cognitively demanding tasks (Stein, Smith, Henningsen, & Silver, 2000). Teachers do so by first making the task accessible to all students (Boaler & Staples, 2008; Hiebert et al., 1997). Next, while students solve the task, teachers assess students' understanding of the key mathematical ideas and advance students' understanding by asking questions about their mathematical reasoning (Smith, Bill, & Hughes, 2008). Teachers then orchestrate a concluding whole class discussion in which they press students to provide evidence and justification for their reasoning, and to make connections between their own and peers' solutions (Chapin, O'Conner, & Anderson, 2003; Staples, 2007). Throughout this process, teachers have a critical role to play in establishing classroom norms and orchestrating discourse. Chapin and colleagues (2003) drew on current research to identify aspects of classroom discourse that are productive in promoting student learning. They describe five talk moves that they have found to be effective: revoicing a students' explanation, asking students to restate someone else's reasoning, asking students to apply their own reasoning to someone else's reasoning, prompting students for further participation, and using wait time. In enacting these talk moves, teachers play a critical role in eliciting mathematical thinking, scaffolding students' ideas, and pressing students

to justify their mathematical ideas to others by giving evidence (Chapin, O'Connor, & Anderson, 2003; Staples, 2007).

Teachers' development of ambitious instructional practices requires a qualitatively different and significantly deeper understanding of mathematics and student reasoning than most teachers currently possess (Ball, 1989, 1996; Cohen & Ball, 1990; Schifter, 1998; Stein, Grover, & Henningsen, 1996). Additionally, the development of ambitious practices requires considerable learning that involves changing deeply held beliefs, knowledge, and habits of practice for practicing teachers, most of whom learned to teach under a different paradigm (Sherin & Han, 2004; Stein, Smith, & Silver, 1999; Thompson & Zeuli, 1999). Substantial support is therefore required for teachers to develop ambitious practices. One increasingly common way to provide support is through content-focused coaching.

Mathematics Coaching as a Form of Professional Development

The number of studies that have examined content-focused coaching is surprisingly small. Some studies have investigated whether coaching either supports teachers' use of specific instructional strategies or improves student achievement, but the results are mixed (Campbell & Malkus, 2011; Cantrell & Hughes, 2008; Gamse, Jacob, Horst, Boulay, & Unlu, 2008; Marsh, McComb, Lockwood, Martorell, Gershwin, & Naftel, 2008; Matsumura, Garnier, & Resnick, 2010; Ross, 1992; Sailors & Price, 2010; VanKeer & Verhaeghe, 2005). Variable implementation is cited as a primary reason for these inconsistent results. For example, the amount and type of coaching that teachers

receive has been shown to differ substantively across schools (Coburn & Russell, 2008; Matsumura, et al., 2009).

Other research has examined the conditions under which content-focused coaching supports teacher learning by identifying aspects of school and district contexts that influence how coaching is implemented (see for example, Coburn & Russell, 2008, Gibbons, 2012b; Mangin, 2005, 2007; Matsumura, et al., 2009). These studies have identified support from the principal as a key aspect of the school context. Specific principal practices identified include: attending professional development sessions about the coaching program (Matsumura et al., 2009), observing classroom instruction and providing teachers feedback (Gibbons, 2012b), publicly endorsing the coach (Matsumura et al., 2009; Mangin, 2007), and regular communication with the coach about mathematics instruction (Gibbons, 2012b; Mangin, 2007). In addition, Coburn and Russell (2008) identified high quality coach professional development as a key aspect of the district context.

Although studies have been conducted to identify school-level aspects support teachers' access to coaches, we know relatively little about what coaches need to know and be able to do in order to engage teachers in activities that are likely to support their development of ambitious instructional practices. Given the underdeveloped state of research on coaching, I turn to the research on professional development and teacher education in order to clarify what coaches might need to know and be able to do to support teachers' development.

The teacher education and professional development research communities have learned a great deal about potentially productive activities that support teachers'

development of practices aimed at ambitious learning goals for students (see for example, Ball, Sleep, Boerst, & Bass, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kazemi & Hubbard, 2008; Lampert, et al., 2010; Putnam & Borko, 2000; Sherin & Han, 2004). In a separate analysis, I drew on this literature to identify activities in which coaches might engage teachers that have the potential to support their development of ambitious instructional practices (see Gibbons, 2012a). I distinguished between potentially productive activities that coaches conduct with groups of teachers (e.g., doing mathematics, examining student work, analyzing classroom video, rehearsing aspects of practice) and activities that coaches conduct with individual teachers in their classrooms (e.g., co-teaching, modeling, and observing instruction and debriefing challenges of implementation).

However, what teacher educators or leaders of professional development need to know is understudied and underdefined (Borko, Koellner, & Jacobs, 2011; Elliott, Kazemi, Lesseig, Mumme, Carroll, & Kelley-Petersen, 2009; Even, 2008). In the absence of empirical research, a number of scholars have speculated about the knowledge and skills that coaches need to develop in order to support teacher' learning (Feger, Woleck, & Hickman, 2004; International Reading Association, 2006; Toll, 2005). Most scholars agree that content-focused coaches need to have developed relatively accomplished instructional practices. However, beyond establishing that coaches need to be relatively accomplished teachers, research has not identified necessary coaching knowledge and practices. Therefore, this analysis seeks to uncover what coaches need to know and be able in order to engage teachers in activities that are likely to support their development of ambitious practices.

Professional Vision for Coaching

The analysis that I report examines aspects of coaching expertise, beyond being a relatively accomplished mathematics teacher. Goodwin (1994) introduced the term *professional vision* to describe how professionals (e.g., archaeologists) see and understand events that are answerable to the distinctive interests of a particular social group. Sherin (2001) built on Goodwin's work by applying the notion of professional vision to teaching. She and her colleagues conducted a number of empirical analyses to examine how teachers moved from novice to expert, and found that their expertise developed in a number of areas including the ways in which they interpreted classroom events (Sherin, 2001; Sherin, 2004; Sherin & van Es, 2005; Sherin & van Es, 2010; van Es & Sherin, 2006; van Es & Sherin, 2008). In this study, I investigate whether it is reasonable both to extend the notion of professional vision to coaching and to expand beyond classroom observation to include a broader range of coaching knowledge.

Overview of Analysis

This study aims to contribute to our understanding of what effective mathematics coaches need to know and be able to do in order to engage teachers in productive activities that provide them with opportunities to develop high quality instructional practices. To do so, I analyze a case of a mathematics coach who consistently engaged teachers in productive activities. My goal in analyzing this case is to develop conjectures about a professional vision as an aspect of coaching expertise that can be examined in future research.

Background

The focal coach in this study was a middle-grades mathematics coach in a large urban district (District B). Leaders in District B aimed to provide students with high quality learning opportunities in mathematics by adopting an ambitious inquiry-oriented curriculum for middle grades mathematics and by providing substantial professional development for teachers and school leaders, including mathematics coaches and principals.

In the 2007-2008 school year, District B adopted the *Connected Mathematics Project 2* (CMP2) curriculum. In order to support teachers in using the new curriculum effectively, the district implemented a school-based content-focused coaching design in which mathematics teacher leaders taught for half of the school day and coached for the other half⁹. District leaders described four goals for coaches' work: (1) to provide one-on-one instructional support to their colleagues in the classroom (e.g., observing and providing feedback), (2) to act as a resource for the principal in matters of mathematics content (e.g., have conversations with the principal about what he/she noticed in a classroom observation), (3) to provide professional development to all middle school mathematics teachers on district professional development days (e.g., workshops on examining student work), and (4) to provide professional development support to their colleagues at their school in group settings (e.g., continue discussions about how to use student work in their practice). In addition, district leaders expected that coaches would be primarily responsible for supporting rather than evaluating teachers.

⁹ Note that in the 2010-2011 school year, many of the schools across the district (including the school examined for this analysis) received a state-funded grant. This grant funded the coaches to work full-time with teachers and did not require them to be the lead teacher for students.

The year before CMP2 was implemented, the district contracted the developers of the curriculum to provide sustained professional development to the mathematics coaches. The intent of this professional development was that coaches would develop both an overview of the curriculum and an understanding what high quality implementation looks like. In preparation for working with teachers, district leaders also provided training in cognitive coaching, an approach that involves asking teachers specific questions designed to help them reflect on their practice. In addition, district mathematics specialists supported coaches in their schools, and coaches could seek advice from them when questions relating to the curriculum and supporting teachers arose.

Methods

Participants

As I have noted, the data that I analyze were collected in the course of a larger study that investigated what it takes to support mathematics teachers' development of ambitious and equitable instructional practices at scale. Researchers conducting the larger study consulted with District B leaders to select a sample of middle schools that were representative of middle schools across the district in terms of capacity for instructional improvement. Seven schools in District B were selected to participate in the study. The participants in each school were approximately five randomly selected mathematics teachers, the principal, any assistant principal responsible for monitoring mathematics instruction, and the mathematics coaches. As I describe in the following

paragraphs, the analysis conducted to select the focal case focused on the teachers and coaches in the seven schools.

Data for case selection

A case study analysis (Yin, 2003) is appropriate given my goal of identifying what coaches need to know and be able to be effective. In order to select a suitable case, I first identified a set of potentially promising coaching activities. This analysis is reported separately and involved examining the professional learning and professional development literature to identify activities that have been shown to support teachers' development of ambitious instructional practices (see Gibbons, 2012a). I used the activities I identified to assess the practices of the seven mathematics coaches in District B who participated in the larger study.

I drew on audio-recorded interviews conducted with the seven coaches and the 32 participating mathematics teachers in their schools January 2009¹⁰ to determine which of the coaches engaged teachers in potentially productive activities. The coach interviews were approximately 60 minutes in length and the teacher interviews approximately 45 minutes. The purpose of the coach interviews was to identify the activities in which coaches engaged teachers, both individually in their classrooms and while working with groups of teachers. In addition to describing types of activities, coaches were asked to provide examples of specific activities.

¹⁰ I chose the 2008-2009 school year in order to identify cases where coaches were productively engaging teachers because this was the 2nd year of CMP2 implementation. I conjectured that during the first year of implementation it was likely that coaches and teachers were more focused on making sense of the new curriculum materials, and in the second year it was more likely that they were engaging in activities that supported the development of ambitious practices.

A primary purpose of the teacher interviews was to understand the supports for their development of ambitious instructional practices, including their interactions with the coach in their school. In order to understand the types of activities that teachers engaged in with coaches and what they learned as a result of engaging in these activities, teachers were asked whether the coach worked with them individually, and if so, to recount a recent example of an activity they did together and the interactions that took place. Additionally, they were asked whether they had ongoing opportunities to meet with other mathematics teachers. If so, teachers were asked to describe the coach's role in these meetings, the types of activities they engaged in, and to recount a recent example of an activity they did together.

Analysis for case selection

I created a coding scheme that was designed to capture the types of activities in which coaches and teachers co-participated (see Appendix A) by reviewing the literature on coaching and supporting teacher learning and from an initial reading of the interview transcripts. I then coded transcripts of the interviews conducted with the seven mathematics coaches and 32 mathematics teachers to determine the extent to which each coach engaged teachers in potentially productive activities. I wrote analytic memos after coding each interview in which I recorded the types of activities in which they engaged, the reported interactions that occurred, and the extent to which the activities were likely to support teachers' development of ambitious instructional practices. In writing these memos, I triangulated the teachers' and the coach's accounts of the activities to ensure

that I did not privilege any participant's account. However, I did not find any significant differences in their accounts to resolve.

Case Selection Findings

I found considerable variation in the types of activities in which the seven coaches engaged teachers. For example, some teachers reported their coach observed their instruction but did not providing any feedback, while others reported co-planning and co-teaching lessons with their coach on a weekly basis. I examined whether aspects of the school contexts could explain this variation. For example, in some schools principals rarely met with coaches, while in other schools the coach and the principal worked together everyday. However, I found that even in schools where coaches had support from principals and regularly scheduled time to work with teachers (see separate analysis, Gibbons, 2012b), there was significant variation in the types of activities coaches engaged in with teachers. This finding suggests that school and district context do not, by themselves, account for the extent to which the coaches engaged teachers in activities that were likely to support their development. It is important to also consider coaches' knowledge when accounting for the variation in their work with teachers.

In order to select an appropriate case, I first assessed whether the seven coaches engaged teachers in activities that are likely to support their development of ambitious practices. One coach was asked by her principal to return to the classroom and teach full-time, and a second was unable to work with the teachers in her school due to poor health. I excluded a third coach because she was new to the school and reported that she did was yet to establish relationships with teachers that would enable her to work with them.

Of the remaining four coaches, two focused primarily on working daily with groups but the activities in which they engaged with teachers involved preparing for upcoming instruction, including examining pacing guides and sharing manipulatives, with very little emphasis on the development specific instructional practices. Therefore, it is unlikely that these meetings supported the development of ambitious instructional practices. Another engaged teacher in activities that focused on issues of classroom management. She explained that this was because all of the mathematics teachers at her school were in their first year of teaching. She intended to support teachers in conducting mathematical investigations with their students by focusing on their questioning techniques. However, mid-way through the school year, her work with teachers still centered on classroom management. Although classroom management is an important aspect of effective teaching, an almost exclusive emphasis on this aspect of instruction is unlikely to support teacher' development of ambitious instructional practices.

The final coach, who I will call Alice, consistently engaged teachers in activities that were likely to support their development teacher' development of ambitious instructional practices. The activities in which she engaged teachers in their classrooms included: modeling, co-teaching, observing and providing feedback, rehearsing, and role-playing. She also co-planned with pairs of same grade level teachers. These activities and subsequent learning opportunities will be described in the findings section.

The middle school in which Alice worked served approximately 500 grade 6-8 students¹¹. Hispanic students made up approximately 95% of the student population, and approximately 95% of the students received free or reduced-price lunch. Roughly 20%

¹¹ This data reflects the 2010-2011 school year and was obtained from the National Center for Education Statistics website (<http://nces.ed.gov/ccd/>). Based on conversations with school leaders, there is reason to believe that this data was similar for 2007-2011.

of the students were classified as English Language Learners and approximately 10% were classified as requiring special education services. There were six mathematics teachers at the school, two per grade level, five of who participated in our study each year. We retained four teachers as participants in the study for four years. For teachers, the average years of experience teaching mathematics¹² was 5.6 years, ranging from 2 to 12 years. The generally supportive school contexts in which Alice worked and in which she was a central source of expertise is described in a separate analysis (see Gibbons, 2012b). Key aspects of the school context included having regularly scheduled meetings with the principal to discuss the progress that mathematics teachers were making and having regularly scheduled time to meet with groups of teachers.

Data for analysis of the focal coach's knowledge and practices

Once I selected the focal case, I analyzed interview data to investigate what the coach needed to know and be able to do in order to successfully engage teachers in potentially productive activities. The data that I analyzed included approximately twenty audio-recorded interviews conducted with the participating teachers in the focal coach's school each January for four years (2008-2011¹³), and four audio-recorded interviews conducted with the coach each January for four years (2008-2011). The coach and teacher interviews had the same focus across the four years of data collection. My intent in analyzing the teacher interviews was to understand the types of activities in which they engaged with the coach both individually and in groups, and the teachers' assessments of

¹² The data reported here is calculated based on the 2008-2009 school year. In the 2009-2010 school year, a first year mathematics teacher was added as a participant.

¹³ I expanded the analysis to look at the activities teachers reported during the yearly interview across 4 years in order to better understand the various types of activities the focal coach engaged in with teachers and whether those changed over the years.

what they learned or developed as a result of engaging in these activities. My intent in analyzing the coach interviews was to understand her views of what good CMP2 implementation looked like, whether she considered that the curriculum was appropriate for all students, her goals for the teachers' learning, and the types of activities in which she engaged in teachers individually and in groups.

I found that the interviews conducted did not enable me to understand why the focal coach chose to engage in specific activities with teachers. I therefore conducted two follow-up interviews; one in December 2011, and a second in March 2012. During these interviews, I asked her to describe how she made decisions about how to assist teachers and why she chose to specific types of activities. I drew on analyses conducted during the larger study of video-recordings of two consecutive lessons taught by the coach and by each of the participating teachers in her school. The video-recordings took place early in the spring semester each year. I drew on all four years of data. The directions given to participants were to include a problem-solving activity and to engage students in a whole class discussion during each lesson. The analyses of these video-recordings provided assessments of the focal coach's and teachers' instructional practices to assess coach's expertise as a mathematics teacher and the teachers' capabilities in relation to coach.

Analysis of the focal coach's knowledge and practices

Once the focal coach was selected, I coded 15 additional teacher interviews and 3 additional coach interviews (years 2007-2008; 2009-2011) using the coding scheme in order to further analyze the extent to which the focal coach engaged teachers in

potentially productive activities. I amended the previous analytic memos and recorded additional activities in which they engaged, the reported interactions that occurred, and the extent to which the activities were likely to support teachers' development of ambitious instructional practices.

I coded the additional focal coach interview transcripts by hand and created analytic memos to document her goals for supporting teachers, how she made decisions about supporting teachers, and why she chose to engage teachers in specific activities. In order to analyze the focal coach's description of high quality CMP2 implementation, I relied on the work of Munter (2010) to classify her instructional vision into two categories: the role of the teacher and the role of discourse. This categorization allowed me to examine her views of what "good" CMP2 instruction entailed. Additionally, I documented her views of whether she considered CMP2 to be appropriate for every student.

As part of the larger project, the video-recordings of the focal coach's and teachers' classroom instruction was coded using the *Instructional Quality Assessment* (IQA) (Matsumura, Slater, Junker, Peterson, Boston, Steele, & Resnick, 2006) in order to assess the quality of their instructional practices. The instrument is consistent with inquiry-based instruction and comprises eight rubrics¹⁴ that focus on the cognitive demand of the instructional tasks used in lessons and the nature of classroom discourse (Stein, et al., 2000). Coders were trained on using the rubrics and had to reach 80% reliability before beginning to code. Ongoing coding reliability was assessed by double-

¹⁴ Potential of the Task, Task Implementation, Academic Rigor of the Discussion, Participation, Teacher Linking, Student Linking, Teacher Asking, and Student Providing. See (Boston & Wolf, 2006) for more information.

coding 20% of the classroom sessions. The overall percent agreement on those double-coded lessons was 73.5%.

Findings

This exploratory study investigates what, in addition to being a relatively accomplished teacher, mathematics coaches need to know and be able to do in order to engage teachers effectively in activities that are likely to support their development of high-quality instructional practices. In the course of the analysis, I identified three important aspects of coaching knowledge, or what I call professional vision for coaching, that comprises: (a) long-term goals for teachers' development, (b) initial trajectories of teachers' development, and (c) a repertoire of learning activities. In addition, I identified three important coaching practices: (a) assessing teachers' current instructional practices, (b) identifying next steps for teachers' development, and (c) selecting from a repertoire of learning activities.

Practice as a Mathematics Teacher

Prior to becoming a part-time coach in the 2006-2007 school year, the focal coach, Alice, taught middle grades mathematics for 10 years at the same school. I used the IQA scores for Alice's instructional practices to determine her expertise as a mathematics teacher. These scores indicate that she had developed relatively sophisticated instructional practices. She was especially effective at asking students to provide evidence for their contributions and at holding them accountable for providing appropriate evidence for their claims. In addition, during the whole class discussions, she

supported students to explain and justify their mathematical reasoning. In 2008, Alice's IQA scores were higher than most (4 out of 5) of the participating teachers in her school, indicating that her instructional practices were more advanced and that she was a more expert other with regards to implementing the CMP2 curriculum. Her IQA scores were relatively stable over the years.

Goals for Teachers' Development

In the interviews conducted with Alice each year, she was asked to describe her goals when she worked with teachers. In the interview conducted in 2009, she replied that "one of them is to help improve their mathematical content knowledge...and (another is) improving their delivery as far as the CMP program goes" (090113). She stated similar goals in the interviews conducted in other three years. I examine each of these goals in more detail below.

Improving mathematical content knowledge. Alice's focus on teachers' mathematics content knowledge reflected her concern that some teachers had inadequate mathematics backgrounds and limited experiences teaching mathematics. For example, Alice observed "our teacher that just came to math this year, she had been teaching English for eight years and didn't really know a lot of the math content" (090113). The five mathematics teachers in Alice's school who participated in our study over the four years had not been trained as mathematics specialists and had 12 credit hours or less of mathematics and mathematics methods courses.

Improving implementation of CMP2. The second related goal that Alice consistently identified was improving teachers' implementation of CMP2. As stated

above, the district adopted CMP2 in the 2006-2007 school year. Previously, teachers had used a more traditional textbook series. The demands placed on the teachers in order to implement CMP2 productively were therefore new for most.

Alice's efforts to realize this goal were oriented by her image of what effective implementation of CMP2 looks like. I refer to this as her *instructional vision*. A coach's instructional vision encompasses her articulated view of aspects of classroom instruction that she considers important together with the rationale for each aspect (Munter & Correnti, 2011). As Alice's instructional vision was remarkably stable over the 4 years of interview data I synthesize those four years into a single account.

Alice's instructional vision

View of the role of the teacher. Alice described the role of the teacher as “not being directive in front of the room,” but instead “being off to the side, facilitating.” According to Alice, the teacher should begin the lesson by leading students into the task, while being careful not to “proceduralize the task.” She also explained that teacher should address key terms of the task and “activate students' prior knowledge.” Once the task has been introduced, Alice explained that students should have an opportunity to work in groups. While students work in groups, the teacher should move around the room in order to “probe and push on students' thinking.” Alice indicated that if students get stuck, the teacher should consider activating prior knowledge by asking questions that may clarify “without giving the mathematics away.” After students have worked in groups, the teacher should lead a whole class in a discussion. The teacher should support students to come up to the board and explain how they thought about the task. During

this phase of the lesson, the teacher should ask questions that “sum up what was learned in the lesson.” Alice explained that it is important for the teacher to assess students’ understanding by “listening to their talk about the task.” Based on this assessment, the teacher should decide if it is necessary to either go back and clarify some ideas, or push their thinking further.

View of the role of discourse. Alice indicated that students should have opportunities to discuss mathematical ideas and share their thinking. While students are exploring the task in small groups, they should be pushing each other to justify their reasoning. Alice indicated that it is important that students are able to work together and have opportunities to “voice out” their thinking. During a concluding whole class discussion, the teacher should invite one group of students to explain how he or she solved the task and should press other students to “restate what the presenting student said in their own words” in order to “strengthen understanding.” The teacher should then call on a different group of students to explain how they solved the task. Alice clarified that the whole-class discussion phase of the lesson is important because students “need opportunities to hear someone else’s way of working through a problem that they may not have thought of themselves.” She also indicated that these discussions enabled her to assess whether a student truly understands the mathematical ideas.

Alice explained that she expected students to question each another and press each other to explain their thinking. In order for students to understand how to ask questions and to make statements in productive ways, Alice believes that the teacher should “model how to have these interactions.” For example, the teacher should assist students in communicating with one another by asking question such as: “Do you agree

with what they said? Why do you agree with them?” In addition, the teacher should press students when they are give explanations: “Say more. Tell me why you thought it was this way. Where did that 3 come from?”

Summary. This analysis of Alice’s instructional vision clarifies her view of what high quality implementation of CMP2 involves. Her vision was relatively sophisticated and was generally aligned with what curriculum developers of CMP2 envision. Alice’s instructional vision clarifies the instructional practices that she aims for teachers to develop in the long term. As I will describe in greater detail, her identification of these long-term goals for teachers’ learning orient her assessments of teachers’ current practices and her decisions about next steps for teachers’ development.

General Trajectories of Teachers’ Development

In addition to establishing long-term goals for teachers’ learning, Alice had also formulated initial trajectories for teachers’ development. These trajectories were grounded in her understanding of teachers’ past practices and of the learning demands inherent in reorganizing those practices. I call these trajectories “initial” because for each teacher, Alice identified a more specific, individualized trajectory based on her assessment of his or her current instructional practices.

Teachers’ prior practices. Alice explained that the new curriculum series differed significantly from the resources that the teachers had used previously:

CMP2 is a very different resource than what a lot of the teachers are used to in the past. With a regular textbook, they followed a Madeline Hunter-type style. Here’s the notes, let’s practice them together, now you do some on your own and here’s your homework. And they were very used to that before we got the CMP2. With CMP2, it’s more of we launch, let’s talk about it a bit, you go try it, let’s

come together as a whole group. It's very different than they were used to.
(120307)

Alice characterized the teachers' prior instructional practices as "stand and deliver" with "lecturing, doing some guided practice and then letting students practice on their own," rather than letting the students "discover the math" (120307). Alice also indicated that when teachers first attempt to change their practices and saw students struggle, they wanted to do a "quick fix" rather than letting students "wade through" challenges. She attributed this to teachers' views of their students capabilities, "I think the teachers need to set their expectations higher, because they are so quick when a student struggles to bring the rigor down and sometimes they bring it down too low for the students" (120307). In addition to considering the starting points in learning to implement the new curriculum effectively, she also differentiated between the learning demands for new and for veteran teachers.

Learning Demands for New and Veteran Teachers. Alice explained that new teachers "typically struggle with the pacing of [the phases of] the lesson" (120307). Alice said that once they have a better grasp of how to pace lessons, she works with them on developing teachers questioning strategies that will "deepen students' thinking" because initially the types of questions that new teachers ask require only a "one-word" answer. She indicated that her subsequent goals for supporting new teachers' learning "varied depending on their practices."

Alice explained that the veteran teachers typically think they need to, "hold their [students'] hand through" the lesson (120307). In her experience, veteran teachers often proceduralize tasks rather than letting students explore the task themselves. Alice initially supported veteran teachers in "activating prior knowledge" at the beginning of

the lesson so that students can be successful on the task without the teacher guiding them all the way through.

Summary. Part of what enabled Alice to engage teachers in potentially productive activities was that she had identified long-term goals for teachers' learning and had developed initial trajectories for new and for veteran teachers' development of ambitious instructional practices. This initial trajectory oriented what she looked for when observing teachers' current instructional practices.

Assessing Teachers' Current Instructional Practices

Alice reported that her specific goals for individual teacher's learning were based on "[her] knowledge of [the] teachers and their strengths and weaknesses," which she identified by "going in their rooms [and] watching them teach" (090113). Alice indicated that she looked for whether teachers made any mathematical errors and for how they dealt with students' mistakes:

If I'm in a classroom and I'm observing and they're making a mistake and they're not going back and correcting it, or if they, if a child's working a problem on the board and they make a mistake and they don't go back and say, 'Oh, wait a minute here, we've got a mistake.' (090113)

Alice clarified that her intent in taking this focus was to determine the teacher's current "content knowledge."

Other aspects of instruction that Alice reported tracking included "student engagement and making sure all students were able to work on the task" and had opportunities to "share their work with the whole class" (110120). Additionally, she focused on how teachers supported students through "questioning strategies," use of "talk moves", and setting "clear expectations" for students (111215). Alice's instructional

vision is implicated in her assessments of teachers' current practices. For example, her instructional vision included an emphasis on discourse that supported students' mathematical learning. This aspect of her vision oriented her assessment of teachers' talk moves and questioning strategies.

In the following excerpt, Alice described a debriefing conversation she had with a seventh grade teacher after observing her instruction:

We planned a lesson together. I had gone to observe and during our post-conference some questions came up of, like, 'How did you know this kid understood because they didn't say a peep the whole time during class? And then did you notice you know this child over here was quick to respond to every single question without giving the other kids a chance to think?' (111215)

While observing the lesson, Alice noticed that the teacher was not supporting students to communicate about their mathematical reasoning and diagnosed what might be leading to these problems. In this example, Alice purposefully assessed the teacher's practices in order to determine the next steps in supporting her to use the curriculum more effectively.

Alice's process of assessing teachers' practices is similar to Sherin's (2001) notion of how individuals view or notice instruction. However, the purpose of teachers' and coaches' noticing is different. Coaches' primary goal is not to directly support students' learning directly, but is instead to assist teachers in improving their current practices. Part of what made Alice an effective coach is the manner in which she interpreted what is going on in the classroom with an eye towards supporting teachers' learning. Alice assessed teachers' current instructional practices by focusing on distinct aspects of instruction, identified next steps in their development, and determined specific activities of in which to engage them.

Identifying Next Steps for Teachers' Development

Once Alice had assessed teachers' current instructional practices with respect to her long-term goals for their learning, she identified aspects of the teachers' instruction upon which she could build. Consider the above example in which a teacher provided insufficient wait time. During the debriefing conversation, Alice pressed the teacher to consider if she knew whether students understood the big mathematical ideas of the lesson. Alice then worked with the teacher to determine the aspect of instruction on which the teacher should work next, which she described as to "get more kids involved in answering questions" (111215). The teacher gave a similar account:

We were thinking about what types of questions I was asking them, and if it was just one person always answering, or if, you know, was it the whole class answering. And so it really helped me realize that it was one person usually answering questions. And so to do it a different way, give 'em a little more think time before one person is always shouting out. (110120)

According to the teacher, Alice assisted her with both the content of questions and how to pose them appropriately to students. In this case, Alice appeared to formulate specific goals for teacher's development against the backdrop of her trajectory for new teachers' learning. As a reminder, Alice reported that she first focused on classroom management and then worked to support teachers to ask deeper level questions. After identifying questioning as the immediate focus, Alice then supported the teacher to consider both the types of questions to ask by engaging her in co-planning, and how to pose these questions and build on students' responses by co-teaching and by observing and providing feedback.

Summary. As the example illustrates, Alice assessed teachers' current practices and she identified immediate goals for their development. Alice's instructional vision

and initial trajectories for teachers' learning that she had formulated oriented her delineation of next steps for individual teachers' development. The delineation of these immediate goals informed and was potentially coincident with selection of activities in which to engage particular teachers.

Coaching Repertoire and Enactment of Activities

In addition to identifying immediate goals for teachers' learning, Alice made decisions about which types of coaching activities were likely to support teachers' achievement of those goals. The activities in which Alice engaged with individual teachers were: modeling, co-teaching, observing and debriefing challenges of implementation, and role-playing. She also engaged pairs of same grade level teachers in co-planning for upcoming instruction. In the following paragraphs, I focus on Alice's rationale for why engaging teachers in these activities would support their development. In addition, I draw on the teachers' accounts of their interactions with Alice to clarify what teachers had opportunities to learn or develop as they engaged in the activities.

Modeling. Alice consulted with a teacher to identify a lesson that she would teach to the teacher's students while the teacher observed. When asked what teachers might learn from modeling, Alice replied, "hopefully...they would see differently the [way] of doing things in the classroom and they would change their practice...[it gives] teachers an example of how a strategy can be done within their own classroom, with their own students" (111215). She provided an example:

If a teacher was taking too long on a warm-up, if they were taking 20 to 30 minutes on one problem that was supposed to be a five-minute problem, I could model that for them and show them how to transition into the next part of the

lesson. And then the more they practiced that, the better they would become at their transitioning and timing (111215)

When Alice modeled instruction, she asked the teacher to focus on a specific aspect of instruction in which she assessed the teacher needed assistance. Alice provided examples of aspects of instruction, including,

[my] presence in the classroom—that I am not just in one corner, that I am moving through the kids. And mainly the questions, the way that I am asking them different things—where I am probing the kids, but not telling them how to do it, because I am trying to get them to come up with different ways to solve the problem (080130).

By identifying specific aspect of instruction for the teacher to focus on, she oriented the teacher’s observations that would serve as a basis for their subsequent conversation.

Most of the teachers (5 out of 7) reported observing Alice model instruction in their classrooms multiple times over the course of the four years of the larger study. About half of the teachers described gaining an image of how CMP2 lessons should unfold when they observed Alice teach (i.e., launch-explore-summarize sequence). For example, when an eighth grade teacher was asked what he “got from” observing Alice, he said:

A more thorough understanding of I guess the focus, if you will, of CMP2. Basically, I guess I would say it was structure, how you would structure a class like that. Like I said before, I am used to being the one in charge of saying, ‘this is what we are going to do, and she taught a very short lesson and the kids worked the rest of the time.’ If I had not seen that, I would still be up here talking to kids, you know and giving them maybe 10 minutes at the end of the period to work on it. (080129)

According to Alice, understanding the pacing of a CMP2 lesson is a first step towards developing high-quality instructional practices and needs to be addressed before focusing on the role of the teacher in supporting students’ learning.

In addition to gaining an image of the structure of CMP2 lessons, Alice aimed to support teachers in improving their understanding of their potential mathematical capabilities and thus in developing higher expectations for their students. A sixth grade teacher recounted that at the beginning of her first year teaching mathematics she would “do a lot of the work and explanation for the students.” However, after watching Alice model instruction in her classroom, she realized that students were capable of doing the mathematics themselves:

[Now] I get the kids to come up and do the problem piece by piece and I'm not actually the one doing any of the work...I learned that slowly, but surely. Seeing [Alice] model that in my class, definitely helped me to realize, oh okay, well the kids can do the work. (100125)

In this case, Alice allowed the teacher’s students to work through mathematical problems themselves, thereby challenging the teacher’s view of their capabilities. Orienting teachers to focus on students’ thinking is a significant step in their development (Franke, Carpenter, Levi, & Fennema, 2001).

Summary. Alice described modeling as a way of supporting teachers’ development of an image of new practices in their classroom, with their own students. She hoped that through modeling, teachers would be able to learn about and then try out new forms of practice. The teachers’ accounts indicate that modeling supported their understanding of the structure of CMP2 lessons and influenced their views of their students’ mathematical capabilities.

Co-teaching. Alice described how her conception of co-teaching had changed over the four years:

Co-teaching when in the beginning...I did it more as, ‘Let me be your assistant. How can I help you in the classroom facilitate things; [do] different activities?’ So I think that helped with just having an extra person in the room to get around to

all the kids in the groups. To help [students] with their questioning, push their thinking further when the teacher may have been held up with a particular student or another group that was struggling. Over time...I would find myself planning more with the teachers and taking more of an active role in the classroom as far as helping with the instruction. So it went more from an aid role during co-teaching to more of I'm also helping your teaching. (111215)

Her later views indicate that she came to see the purpose co-teaching as support teachers' learning rather than merely providing an extra pair of hands. When asked specifically what she hoped teachers would learn, Alice responded, "Mainly, I would say coming up with questioning strategies that they may not have thought of on their own; that I may have brought out into the classroom...when I wasn't there they could bring those questions in their discussions" (111215).

A majority of teachers (5 out of 7) reported engaging in co-teaching with Alice across multiple years. A sixth grade teacher gave an example of what they worked on during co-teaching. She reported that Alice typically assisted her in preparing for whole class discussions:

If [Alice] sees that a student has done it a different way, she'll point out 'so-and-so did it this way'...So whenever we go over the answers or talk about what we've done, she'll say, 'oh, so-and-so did it this way, you know, why don't you go up to the board?' So she knows the kids in my classroom...She'll help me out and call up the kids (110120).

Through co-teaching, Alice supported the teacher's development of the complex practice of orchestrating whole class discussions by assisting her to select which students should present, and justifying those suggestions in terms of the solution strategies particular students had used. Alice's interview responses indicate that she might also have assisted the teacher in posing various questions to students during the whole class discussion phase, which could have further supported the teacher's development of this complex practice.

This example highlights that in order for co-teaching to be successful, the coach must have established a relationship of trust with the teacher. Alice explained that a history of working together supports the activity:

Some teacher[s]—based on our past history together and be[ing] comfortable with each other—I knew that if I had a question that I wanted to pose to the kids that I could just jump in and ask it to the class. And we would feed off each other.
(111215)

Summary. Co-teaching allowed Alice to support teachers by directly inserting questions into a lesson that teachers could then practice on their own in subsequent classes. Co-teaching provided teachers opportunities to co-participate in making significant instructional decisions with a more accomplished colleague and in classroom interactions that Alice initiated.

Debriefing challenges of implementation. Debriefing was an important part of Alice’s repertoire. With any in-classroom activity, whether it is modeling, co-teaching, or observing, Alice and the teachers both reported consistently that they had follow-up debriefing conversations. Alice explained how she typically structured a debriefing session when she observed a teacher’s instruction, which was remarkably stable across the 4 years:

After I go observe them, and then we’ll sit down together and I’ll ask them, ‘What went well? What do you think didn’t go well?’ And then we’ll talk about it; and then we’ll come up with some goals for them to try and achieve and work on.
(090113)

Alice also indicated that she and the teacher would typically negotiate a goal for instructional improvement and make a plan for how to proceed. In developing the plan, Alice would propose an activity, such co-teaching, that she conjectured would help the teacher improve his or her instruction.

While there were not useful examples from the teacher interview data describing what they learned from debriefing conversations, Alice provided an illustration of a conversation she had with a teacher about pacing:

Another teacher, their specific goal was transition and pacing... if you tell the kids you've got five minutes to do a task but then you end up giving 'em 15 because you've lost track of time, it kind of throws everything of course. So helping that teacher stick to the five minutes...[I said], 'hey I noticed you know you told them five minutes but you gave 'em 15, you know. Have you used the timer on the Promethean Board and how has that worked for you?' (111215)

As this example shows, debriefing allows Alice to discuss which aspects of practice they could improve upon, negotiate goals with teachers and discuss how to move forward in order to develop those practices.

Summary. Debriefing was an important part of Alice's repertoire that allowed her to support teachers to reflect on specific aspects of instruction and assess their progress in improving those aspects. The use of debriefing also allowed her to support teachers in a reflective analysis of classroom events that just occurred, and negotiate immediate goals.

Co-planning. Alice engaged pairs of teachers¹⁵ who taught the same grade level in co-planning. Through co-planning, Alice hoped in part to support teachers to improve their mathematical knowledge for teaching. She gives an example of supporting an eighth grade teacher:

Our teacher that just came to math this year, she had been teaching English for eight years and didn't really know a lot of the math content—especially for 8th grade, it's very complex. So we'll go through the lessons together and we'll plan together with the other eighth grade teacher, and we'll kind of go through the content with her. (090113)

¹⁵ From 2006-2009 in addition to coaching, Alice taught 8th grade students. Therefore, she only had time to co-plan with the other 8th grade teacher. In the 2010-2011 school year, when she became a full time coach, she led co-planning for all of the teachers during their grade level planning meetings.

Alice typically pressed teachers to consider the mathematics in the investigation that they planned to use by asking: “What would the kids need to know before they got to this lesson? What’s the new math coming out of it? How are we going to address any misconceptions or areas where the kids might struggle?” (111215). In addition, Alice pressed teachers to consider how the lesson might play out: “Figure out, how we were going to get...from the time your kids walk in until the time the kids left, what were the kids going to be doing? What kinds of questions were you going to be asking them? What kinds of materials or manipulatives were you going to use?” (111215). Her intent in posing these types of questions was to support the teachers to consider their role in supporting students to engage in the lesson and to identify what the students would be doing in each phase of the lesson. This in turn helped Alice meet her objective of supporting teachers in pacing lessons appropriately.

All of the teachers report engaging in co-planning. Most teachers described this activity as going through a chapter in the curriculum and discussing the activities in each lesson, responding to questions such as: “Where is the problem going? What it’s wanting the student to learn?” (sixth grade teacher, 100125). New teachers indicated that they benefited from co-planning with Alice and other veteran teachers. For example, a new eighth grade teacher reported this activity to be especially helpful:

I’ll be like, ‘For 3.2, what did you do?’ ...I would ask, ‘Well there’s A through D on this problem. I really don’t like the way they phrased D, is there another way that you did it? You know, did you do this certain problem? Did you do this in group work? Did you do, you know, was this one of our poster activities or did you have us do individual work?’ (100125).

Veteran teachers also reported benefitting from co-planning. For example, a seventh grade teacher said that in co-planning she often discussed how she and other teachers had

taught particular lessons the previous year, and whether they wanted to use the “same activity or improve it for this year” (100125).

Summary. By asking these types of questions during co-planned, Alice pressed the teachers to consider the mathematics and how it fit into a larger sequence of lessons, to anticipate what students would do, and to generate potential questions that would promote student learning. This approach to planning was consistent with her long-term goals for teachers’ development.

Summary of Alice’s Repertoire of Activities. The generation of ideas for learning activities is dependent on Alice’s conjectures about the learning process. Alice had developed explicit rationales about how different types of activities—modeling, co-teaching, observing and debriefing challenges of implementation, and co-planning—could support teachers’ learning. Having a repertoire of activities allowed Alice to better establish immediate goals for individual’s learning. Alice has to consider which specific coaching activities are likely to support teachers to understand and develop different aspects of instruction. Therefore, her identification of immediate goals and hypotheses about activities are closely related.

Discussion

This study contributes to the very limited literature on what mathematics coaches need to know and be able to do in order to engage teachers in productive activities that support their development of ambitious instructional practices. As mathematics coaching becomes central in many districts’ professional development designs, we need to understand what is entailed in the complex work of supporting teachers’ development.

Therefore, I examined the knowledge and practices of one mathematics coach who consistently engaged teachers in activities that were likely supporting their development. This analysis suggests three important aspects of coaching knowledge, or what I call professional vision for coaching, which comprises: (a) long-term goals for teachers' development, (b) initial trajectories of teachers' development, and (c) a repertoire of learning activities. In addition, this analysis suggests important coaching practices: (a) assessing teachers' current instructional practices, (b) identifying next steps for teachers' development, and (c) selecting from a repertoire of learning activities. As this case analysis was exploratory, further research is needed to clarify the extent to which the identified knowledge and practices characterize the work of coaches who engage teachers in productive activities more generally.

The case suggests the potential importance of coaches developing goals for teachers' development. The focal coach identified two goals for supporting teachers' reorganization of their instructional practices: improving their mathematics content knowledge and improving their implementation of curriculum. The case therefore suggests that in addition to having relatively sophisticated mathematical knowledge for teaching and accomplished instructional practices, it might also be important that coaches have developed sophisticated instructional visions. Coaches' instructional visions are important for three additional reasons. First, it clarifies long-term goals for teachers' learning by providing an image of what an effective classroom looks like. In other words, this image indicates the types of instructional practices that they desire to support teachers to develop. Second, coaches might assess teachers' current practices against this end point to identify what they can build upon. Third, coaches' articulation of their

instructional visions might enable them to decompose instruction, name the component practices, and translate them into diagnoses for teachers in order to establish concrete, workable goals for teachers' learning.

This analysis also clarifies how effective coaches might individualize supports for teachers by identifying more immediate goals for teachers' learning. The focal coach's formulation of immediate goals was oriented by her long-term goals and informed by her assessment of teachers' current practices and the general trajectories she had developed for their learning. The analysis also suggests that effective coaches have a repertoire of coaching activities from which to select, depending on the identified learning goals for a teacher. Once the immediate goals were identified, the focal coach drew upon her repertoire of coaching activities to select an appropriate activity to engage teachers. Underlying the focal coach's beliefs about which types of activities were likely to support teachers' development of different aspects of practice were her views of teacher development.

This process of formulating goals and selecting activities for supporting others' learning is analogous to that of experts who have examined their own practices. Cobb and Gravemeijer explained how they prepared for a classroom design experiment, in which they aimed to develop, test, and refine instructional sequences in a particular mathematical domain (Cobb & Gravemeijer, 2008). When they formulated goals for students' learning, they first documented the instructional starting points to identify the aspects of students' current reasoning on which they would build. The researchers reported that these decisions were oriented by long-term goals for student's learning and envisioned learning trajectories. Similarly, Simon provided an account of his decision-

making as a mathematics teacher whose practice was oriented by constructivist view of mathematical learning (Simon, 1995). He identified what he termed a *hypothetical learning trajectory*, which he explained “provides the teacher with a rationale for choosing a particular instructional design” (Simon, 1995, p. 135). Two of the components of the hypothetical learning trajectory are identifying the learning goals and planning learning activities. While the intended targets of support differ among instructional designers, mathematics teachers and mathematics coaches, the processes by which the “more knowledgeable other” identifies potential supports are similar. The processes include the importance of formulating supports by taking into account the learners’ current practices—which are oriented by long-term goals and potential learning trajectories—and specifying the means of supporting that learning.

This analysis indicates the value of coaches developing an understanding of the paths of teachers’ learning as they develop inquiry-oriented instructional practices. The focal coach had formulated general trajectories for teachers’ development. For example, she believed that new teachers had to first become proficient at pacing the phases of lessons, and then support student engagement before they could focus on supporting the development of students’ understanding by, for example, improving their questioning strategies. Similar to this aspect of the focal coach’s professional vision, Schoenfeld (2010) has identified three main planes of teachers’ professional activity. The first plane is learning to orchestrate classroom activities; this is typically called “classroom management” and represents the work of getting to the point where the classroom operates effectively. The second plane is developing activities to enable students to engage with the content, but the focus is still activity or content centered and there is not

yet a focus on grappling with student understanding. The third plane is recognizing that diagnosing students' understanding of the content is a starting point for classroom activities, and that the challenge is to sequence activities so as to support students' development of a deeper understanding. Schoenfeld found that novice teachers typically spend more time on classroom management and implementing activities intended to engage students. In contrast, proficient teachers typically focus primarily on diagnostic teaching. Schoenfeld's analysis suggests that the focal coach's trajectories of teacher development might be applicable other mathematics coaches as they consider how to provide individualized supports.

For ease of explanation, it was necessary to pull apart the aspects of professional vision and practices. However, coaches' knowledge and practice are interdependent. For example, when the focal coach planned for and enacted supports for teachers, she relied on her professional vision for coaching. When assessing teachers' current instructional practices, she relied on her vision of high quality instruction. It is also important to note that goals are established prior to acting can later be modified (Steffe, 1991). It is likely that immediate goals change based on coaches' reassessment of the situation or in reaction to new information received. Hence, coaches might plan for the ways in which they will support teachers, but purposeful actions are inevitably situated in the context of particular concrete circumstances (Suchman, 1987). Therefore, coaches' actions may be revised as circumstances play out.

Because this analysis was exploratory, additional research is needed to support or further investigate this set of conjectures about coaching knowledge and practices. Future studies need to examine the practices of multiple coaches who appear to be

effective in supporting teachers' development of ambitious instructional practices to expand on the concept of professional vision of coaching. Specifically, we need to better understand: how coaches view teachers as learners; what coaches focus on when observing teachers' instructional practices; the process by which they assess teachers' current instructional practices; how they make decisions about teachers' practices on which they can build; and what influences coaches' professional vision and practices.

Additionally, studies need to examine the interactions that take place between effective coaches and teachers in order to better understand what teachers learn from working with coaches. What influences who initiates the assistance? What types of interactions support teachers' development? How do teachers make sense of and incorporate coaches' recommendations? How do coach and teacher interactions change over time as teachers develop more sophisticated practices?

This proposed line of work will have implications for the field of content-focused coaching, as well pragmatic implications. By identifying how effective coaches use their knowledge and practice to provide high quality supports for teachers, district leaders may better understand whom to hire for these positions. In addition, district leaders and professional development providers can better identify the types of learning opportunities content-focused coaches need in order to develop coaching practices that are likely to support teachers' development.

References

- Ball, D. L. (1989). Research on teaching mathematics: Making subject matter knowledge part of the equation. In J. Brophy (Ed.), *Advances in research on teaching: Teacher's subject matter knowledge and classroom instruction* (Vol. 2, pp. 1-48). Greenwich, CT: JAI Press.
- Ball, D. L. (1996). Connecting mathematics as part of learning to teach. In D. Shifter (Ed.), *What's happening in math class: Reconstructing professional identities* (Vol. 2, pp. 36-45). New York: Teachers College Press.
- Ball, D. L., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *Elementary School Journal*, 109(5), 458-474.
- Boaler, J., & Staples, M. (2008). Creating mathematical futures through an equitable teaching approach: The case of Railside School. *Teachers College Record*, 110, 608-645.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Borko, H., Koellner, K., & Jacobs, J. (2011). Meeting the challenges of scale: The importance of preparing professional development leaders. *Teachers College Record*, Date Published: March 04, 2011. Retrieved from <http://www.tcrecprd.org> ID Number: 16358.
- Campbell, P. D., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal* 111(3), 430-454.
- Cantrell, S. C., & Hughes, H. K. (2008). Teacher efficacy and content literacy implementation: An exploration of the effects of extended professional development with coaching. *Journal of Literacy Research*, 40, 95-127.
- Chapin, S., O'Connor, C., & Anderson, N. (2009). *Classroom Discussions: Using math talk to help students learn*. Sausalito, CA: Math Solutions.
- Cobb, P. & Gravemeijer, K. (2008). Experimenting to support and understand learning processes. In A. E. Kelly, R. Lesh, and J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching*. New York: Routledge.
- Coburn, C. E., & Russell, J. L. (2008). District Policy and Teachers' Social Networks. *Educational Evaluation and Policy Analysis*, 30(3), 203-235.

- Cohen, D. K., & Ball, D. L. (1990). Policy and practice: An overview. In D. K. Cohen, P. L. Peterson, S. Wilson, D. L. Ball, R. Putnam, R. Prawat, R. Heaton, J. Remillard & N. Wiemers (Eds.), *Effects of state-level reform of elementary school mathematics curriculum on classroom practice*. East Lansing, MI: The National Center for Research on teacher Education and The Center for the Learning and Teaching of Elementary Subjects, College of Education, Michigan State University.
- Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Palo Alto, CA: Stanford University and National Council of Staff Development.
- Elliott, R., Kazemi, E., Lesseig, K., Mumme, J., Carroll, C., & Kelley-Petersen, M. (2009). Conceptualizing the work of leading mathematical tasks in professional development. *Journal of Teacher Education*, 60, 364-379.
- Even, R. (2008). Facing the challenge of educating educators to work with practicing mathematics teachers. In T. Wood, B. Jaworski, K. Krainer, P. Sullivan & T. Tirosch (Eds.), *The international handbook of mathematics teacher education: The mathematics teacher educator as a developing professional* (Vol. 4). Rotterdam, The Netherlands: Sense.
- Feger, S., Woleck, K., & Hickman, P. (2004). How to develop a coaching eye. *Journal of Staff Development*, 25(2), 14-18.
- Frank, K. A., Zhao, Y., & Borman, K. (2004). Social capital and the diffusion of innovations within organizations: The case of computer technology in schools. *Sociology of Education*, 77, 148–171.
- Franke, M. L., Carpenter, T. P., Levi, L., & Fennema, E. (2001). Capturing teachers' generative change: A follow-up study of professional development in mathematics. *American Educational Research Journal*, 38, 653–689.
- Franke, M. L., & Kazemi, E. (2001). Teaching as learning within a community of practice: Characterizing generative growth. In T. Wood, B. Nelson, & J. Warfield (Eds.). *Beyond classical pedagogy in elementary mathematics: The nature of facilitative teaching* (pp. 47-74). Mahwah, NJ: Lawrence Erlbaum.
- Franke, M. L., Kazemi, E., & Battey, D. (2007). Mathematics teaching and classroom practice. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 225-256). Greenwich, CT: Information Age Publishers.
- Gamse, B. C., Jacob, R. T., Horst, M., Boulay, B., & Unlu, F. (2008). *Reading First impact study final report* (NCEE 2009-4038). Washington, DC: National Center

for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

- Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4).
- Gibbons, L. K. (2012a). Examining professional learning literature to identify potentially productive coaching activities. (Unpublished doctoral dissertation). Vanderbilt University, Nashville, TN.
- Gibbons, L. K., (2012b). How aspects of the school setting and coach characteristics influence coach centrality. (Unpublished doctoral dissertation). Vanderbilt University, Nashville, TN.
- Goodwin, C. (1994). Professional Vision. *American Anthropologist*, 96, 606-633.
- Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K. C., Wearne, D., & Murray, H. (1997). *Making Sense: Teaching and Learning Mathematics with Understanding*. Portsmouth, NM: Heinemann.
- International Reading Association. (2006). Standards for middle and high school literacy coaches. Newark, DE: Author.
- Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, 7, 203–235.
- Kazemi, E., Franke, M. L., & Lampert, M. (2009). *Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction*. Paper presented at the annual meeting of the Mathematics Education Research Group of Australia. Wellington, New Zealand.
- Kazemi, E., & Hubbard, A. (2008). New directions for the design and study of professional development: Attending to the coevolution of teachers' participation across contexts. *Journal of Teacher Education*, 59, 428-441.
- Kilpatrick, J., Swafford, J., and Findell, B. (Eds.) (2001). *Adding it up: Helping children learn mathematics*. Washington, D.C.: National Academy Press.
- Lampert, M., Beasley, H., Ghouseini, H., Kazemi, E., & Franke, M. L. (2010). Using designed instructional activities to enable novices to manage ambitious mathematics teaching. In M. K. Stein & L. Kucan (Eds.), *Instructional explanations in the disciplines* (pp. 129-141). New York: Springer.

- Lampert, M., & Graziani, F. (2009). Instructional activities as a tool for teachers' and teacher educators' learning. *The Elementary School Journal*, 109(5), 491-509.
- Lappan, G. (1997). The challenges of implementation: Supporting teachers. *American Journal of Education*, 106, 207-239.
- Marsh, J., McCombs, J., Lockwood, J. R., Martorell, F., Gershwin, D., Naftel, S., Le, V., Shea, M., Barney, H., & Crego, A. (2008). Supporting literacy across the sunshine state: A study of Florida middle school reading coaches. Santa Monica, CA: Rand Corporation. http://www.rand.org/pubs/research_briefs/RB9374/
- Mangin, M. M. (2005). Teacher leadership and instructional improvement: Teachers' perspectives. In W. K. Hoy & C. Miskel (Eds.), *Contemporary issues in educational policy and school outcomes* (pp. 159-192). Greenwich, CT: Information Age Publishing.
- Mangin, M. M. (2007). Facilitating Elementary Principals' Support for Instructional Teacher Leadership. *Educational Administration Quarterly*, 43(3), 319-357.
- Matsumura, L. C., Garnier, H. E., Resnick, L. (2010). Implementing literacy coaching: The role of school social resources. *Educational Evaluation and Policy Analysis*, 32(2), 249-272.
- Matsumura, L. C., Sartoris, M., Bickel, D. D., & Garnier, H. E. (2009). Leadership for literacy coaching: The principal's role in launching a new coaching program. *Educational Administration Quarterly* 45(5) 655-693.
- Matsumura, L. C., Slater, S. C., Junker, B., Peterson, M., Boston, M., Steele, M., & Resnick, L. (2006). Measuring reading comprehension and mathematics instruction in urban middle schools: a pilot study of the instructional quality assessment. National Center for Research on Evaluation, Standards, and Student Testing (CRESST) Report #681.
- McLaughlin, M. W., & Talbert, J. E. (2006). *Building school-based teacher learning communities: Professional strategies to improve student achievement*. New York: Teachers College Press.
- Munter, C. (2009). Defining visions of high-quality mathematics instruction. In S. L. Swars, D. W. Stinson, & S. Lemons-Smith, (Eds.), *Proceedings of the Thirty First Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 983-991). Atlanta, GA: Georgia State University.
- Munter, C. & Correnti, R. (2011). Developing visions of high-quality mathematics instruction. Paper presented at the annual meeting of the National Council of Teachers of Mathematics. Indianapolis, IN.

- National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: author.
- Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity, promises and practicalities*. Washington, DC: Aspen Institute Program on Education and Annenberg Institute for School Reform.
- Poglinco, S. M., Bach, A., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003). *The heart of the matter: The coaching model in America's Choice schools*. Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.
- Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4-15.
- Ross, J. (1992). Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education*, 17(1), 51-63.
- Sailors, M. & Price, L. (2010). Professional development that supports the teaching of cognitive reading strategy instruction. *The Elementary Journal*, 110(2), 301-322.
- Schifter, D. (1998). Learning mathematics for teaching: From a teachers' seminar to the classroom. *Journal of Mathematics Teacher Education*, 1, 55-87.
- Sherin, M. G. (2001). Developing a professional vision of classroom events. In T. Wood, B. Scott Nelson, J. Warfield (Eds.) *Beyond classical pedagogy: Teaching elementary school mathematics* (pp. 75-93). Mahwah, NJ: Erlbaum.
- Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Advances in research on teaching: Using video in teacher education*, 10 (1-27). Oxford, UK: Elsevier.
- Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of video club. *Teaching and Teacher Education*, 20, 163-183.
- Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, 13(3), 475-491.
- Schoenfeld, A. H. (2010). *How We Think: A Theory of Goal-Oriented Decision Making and its Educational Applications*. New York: Routledge.
- Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education* 26(2), 114- 145.

- Smith, M. S., Bill, V. & Hughes, E. K. (2008). Thinking through a lesson: Successfully implementing high-level tasks. *Mathematics Teaching in the Middle School*, 14, 132-138.
- Staples, M. (2007). Supporting whole-class collaborative inquiry in a secondary mathematics classroom. *Cognition and Instruction*, 25(2), 161-217.
- Steffe, L. (1991). The constructivist teaching experiment: Illustrations and implications. In E. von Glasersfeld (Ed.), *Radical constructivism in mathematics education*, (pp. 177-194). Dordrecht The Netherlands: Kluwer.
- Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal*, 33, 455-488.
- Stein, M. K., Smith, M. S., Henningsen, M. A., & Silver, E. A. (2000). *Implementing standards-based mathematics instruction: A casebook for professional development*. New York: Teachers College Press.
- Suchman, L. (1987). *Plans and Situated Actions: The Problem of Human-Machine Communication*. Cambridge, UK: Cambridge University Press.
- Thompson, C. L., & Zeuli, J. S. (1999). The frame and tapestry: Standards-based reform and professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341-375). San Francisco: Jossey-Bass.
- Toll, C. A. (2005). *The Literacy Coach's Survival Guide*. Newark, DE: International Reading Association.
- U.S. Department of Education. (2008). *The final report of the National Mathematics Advisory Panel*. Washington, DC: Author.
- van Es, E. A., & Sherin, M. G. (2006). How different video club designs support teachers in "learning to notice". *Journal of Computing in Teacher Education*, 22(4), 125-135.
- van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, 24, 244-276.
- van Es, E.A. & Sherin, M.G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, 13, 155- 176.
- Van Keer, H., & Verhaeghe, J. P. (2005). Comparing two teacher development programs for innovating reading comprehension instruction with regard to teachers' experiences and student outcomes. *Teacher and Teacher Education*, 21, 543-562.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 173-210). Washington, DC: American Educational Research Association.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Appendix A

Coding Scheme for Analysis of Interview Data

The following pages contain the parts of the coding scheme that was used to code interview data. The coding scheme was created with categories that were developed from reviewing the literature on coaching and supporting teacher learning and from an initial reading of the interview transcripts (e.g., based on the questions that were asked and the participants' responses).

The software that I used to code the interview data is NVivo9. The codes were created in NVivo and exported into a table; the first four columns of the table below were copied directly from NVivo. They contain the seven parent nodes, and the corresponding child nodes. The column on the right contains definitions for each of the nodes.

Parent Node	Child Node	Child Node	Child Node	Definition of code
0 Coach Personal				About the coach
	0.1 History			History
		0.1.1 Before Coaching		"What did you do before you became a coach? Where?"
		0.1.2 How long coaching		"How long have you been working as a coach?"
	0.2 C reaction to transition			"How difficult was it to transition from a teacher to a coach?"
	0.3 Hiring			"Who hired you for this position? What was the process?"
	0.4 C goals			Coaches goal for working with teachers
	0.5 C Challenges			What are some major challenges that you have experienced in supporting teachers' learning?
	0.6 C on effective ways to support T			"What do you think are effective ways to support math teachers in improving their classroom practice?"
4 Activities focused within Ts class time_one-on-one				IN THE CLASSROOM
	4.1 Co-teach			Coach and Teacher both teach lesson(s) together

	4.4 C is extra set of hands in classroom			Coach is an extra set of hands while teacher teaches (e.g., C works with groups of students while in T classroom)
	4.5 C helps with classroom management			Coach assists with classroom management in classroom
	4.2 Model lessons			Coach models lesson for teacher
	4.6 Feedback			
		4.6.1 Classroom Management		Coach gives feedback around classroom management
		4.6.10 No feedback mentioned		Coach observes Teacher, no feedback
		4.6.2 Mathematics content		Coach gave feedback around mathematics content
		4.6.3 Student learning		Coach gives feedback around student learning
		4.6.4 Student work		Coach gives feedback around student work
		4.6.5 LEP_ELL		Coach gives feedback around LEP/ELL
		4.6.6 Special Education		Coach gives feedback around Special Education
		4.6.7 Curriculum		Coach gives feedback around curriculum
		4.6.8 Instruction_Pedagogy		Coach gives feedback around instruction/pedagogy
		4.6.9 Other		Coach gives feedback around other (e.g., maintaining rigor of task, accountable talk), or not specific
	4.3 C Observes T_conference			Coach engages in coaching cycle with teacher (existence); code content of feedback in 4.6

	4.7 Coach does not work with teacher in classroom			Coach does not work with teacher in his/her classroom
5 Activities outside of class time, with_for Ts				With groups of teachers
	5.10 T does not work outside of class with C			Teacher does not work outside of class with coach
	5.11 C and novice Ts			
		5.11.1 C is T's official mentor		Coach is the teacher's official mentor (novice teacher)
		5.11.2 C spends time with novice Ts		Teacher indicates that the coach spends a lot of time with novice teachers (a majority of her time with novice T)
	5.13 Other			Coach does other things outside of working with teachers
	5.3 C provides material resources to T			Coach provides material resources to the teacher
	5.5 Content of C and T conversations, individual T			Coach meets with teacher outside of classroom, but not in whole group setting (could be pre-discussion for a coaching cycle)
		5.5.1 Classroom management		Coach discusses classroom management strategies
		5.5.10 Literacy Strategies		Coach discusses literacy strategies
		5.5.11 Lesson Plans		Coach discusses/co-creates lesson plans

		5.5.3 Assessment data		Coach discusses assessment data
		5.5.12 Other		Other
		5.5.2 Instruction		Coach discusses mathematics instructional practices (e.g., launch, small groups)
		5.5.4 S learning		Coach discusses how students are learning/making progress
		5.5.5 S work		Coach examines student work
		5.5.6 LEP_ELL		Coach discusses strategies for LEP/ELL students
		5.5.7 Special education		Coach discusses strategies for SPED students
		5.5.8 Mathematics Content		Coach examines math content
		5.5.9 Curriculum		Coach examines curriculum
	5.4 Content of C and T conversations, formal groups of T			Conversations with groups of teachers (e.g., during weekly instructional planning meetings)
		5.4.1 Classroom management		Coach and teachers have discussions around classroom management
		5.4.10 Literacy Strategies		Coach and teachers have discussions around literacy strategies
		5.4.11 Lesson Plans		Coach and teachers have discussions around lesson plan
		5.4.3 Assessment data		Coach and teachers have discussions around assessment data (e.g., benchmark data, individual students, group of students)
		5.4.12 Other		
		5.4.2 Instruction		Coach and teachers have discussions around mathematics instruction (PCK-type issues)

		5.4.4 S learning		Coach and teachers have discussions around student learning
		5.4.5 S work		Coach and teachers have discussions around student work
		5.4.6 LEP_ELL		Coach and teachers have discussions around LEP/ELL students
		5.4.7 Special education		Coach and teachers have discussions around special education students/strategies
		5.4.8 Mathematics Content		Coach and teachers have discussions around mathematical content
		5.4.9 Curriculum		Coach and teachers have discussions around curriculum
	5.5 C keeping Ts on Pacing			Coach monitors teacher adherence to pacing guide
	5.6 T shares resources with C			Teacher shares resources with coach
	5.8 Existence of informal discussions with C and T			Coach and teacher have informal discussions (i.e., in the hallway or copy room); code content under 5.5
	5.9 C helps other T, but not me			Coach helps other teachers, but not "me"