Investigating Relationships between Understanding of Inquiry Mathematics, District Context, and School Context on Principal Instructional Leadership Aimed at Ambitious Instruction

By

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For Daniel, and his Lion Heart.

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CHAPTER 1

INTRODUCTION

In many school settings, school leaders (e.g. principals and assistant principals) are expected to be instructional leaders who work with instructional coaches and teachers to improve student learning and the quality of instruction (Elmore 2000; Cobb & Jackson 2011b; Fink & Resnick 2001). Over the last few decades, several studies have found that effective principals tend to be in schools with higher-than-expected student achievement, particularly if the principal is viewed by teachers as a strong instructional leader (Robinson et al. 2008; Leithwood et al. 2004; Hallinger & Heck 1998; Edmonds 1979; Neumerski 2013; Bryk et al. 2010). Researchers have identified practices for principals who are effective instructional leaders, such as establishing shared goals for student learning and instruction, promoting and providing resources for teacher collaboration, ensuring teachers have ongoing support through coherent and content-based professional development (PD), and strategically managing resources to sustain focus on goals for student learning and instruction. Additionally, researchers have found that it is imperative for school leaders to support joint work on goals for improvement through fostering relational trust (Bryk & Schneider 2002). Furthermore, given the complexity of schools as organizations, it is important that schools have multiple instructional leaders who fulfill complementary roles (Elmore 2006; Spillane et al. 2004; Higgins & Bonne 2011).

Despite evidence on how effective principals can improve school outcomes, it is still unclear how school leaders' instructional leadership practices influence instruction (Neumerski 2013; Spillane et al. 2004; Stein & Nelson 2003). The majority of research on instructional leadership has not analyzed how principals frame the problem of improving student learning and instruction in relation to particular student learning goals. Also, research has typically not analyzed how principal instructional leadership is enacted and how it influences the nature of instruction in substantial ways (Spillane et al. 2004). This gap in the research is important to address given that the implementation of more ambitious student learning goals, such as the Common Core State Standards in Mathematics (Common Core State Standards in Mathematics [CCSSM], 2010), require significant teacher learning and reorganization of instructional practices (Cobb & Jackson 2011a). Given that school leaders are increasingly positioned as central instructional leaders responsible for improving student learning, it is imperative to understand what principals need to know and do to support instructional improvement. Thus far, mathematics educators have found that principals can impede instructional improvement efforts through redirecting the work of instructional coaches, pressing teachers to use curricula in ways that are counter to its design, and pressing teachers to improve test scores on procedurally-oriented state assessments (Manouchehri & Goodman 1998; Coburn & Russell 2008). Broadly, math educators acknowledge that principals play an important role in supporting implementation of the CCSSM; however, the specifics of what principals need to know and do have yet to be specified (National Council of Teachers of Mathematics [NCTM], 2014).

There is some evidence that how school leaders frame the problem of improving student learning in relation to external policies can influence the activities and content of professional development and teacher collaboration, which in turn can influence teachers' instructional practices (Coburn 2006; Coburn 2005). Through problem framing, school leaders can influence how teachers adapt instruction in relation to external policies. Additionally, Coburn (2005, 2006) found that school leaders can leverage their position as evaluators to persuade teachers to implement external policies. Importantly, school leaders can adapt external policies through framing the problem of improving student learning (diagnostic frame) in relation to their understandings of external policies. In response to these problem statements, school leaders can implement strategies for improving student learning (prognostic frame). For my dissertation, I focus on how school leaders problematize current math instruction and student learning in relation to ambitious goals for student learning. I also focus on how principals implement strategies in response to these problems (Benford & Snow 2000). With regards to the CCSSM, I conjecture that school leaders need to frame the problem of improving student learning as one that requires significant reorganization of teachers' current instructional practices. (Cobb & Jackson 2011a; Cobb & Jackson 2011b).

Prior studies have found that school leaders' understanding of teaching and student learning in a given content area can influence their diagnostic and prognostic frames (Burch & Spillane 2003; Nelson 1997; Stein & Nelson 2003). With regards to *inquiry-oriented mathematics instruction*, there is some evidence that principals with a functional understanding of this instruction are more likely to identify instructional problems that limit students' opportunities to develop a conceptual understanding of mathematics (Nelson & Sassi 2005). There is also evidence that principals with a functional understanding of inquiry-oriented math instruction are more likely to endorse strategies that have the potential to improve instruction, such as assigning expert facilitators who can guide teachers through upcoming mathematical investigations (Nelson, 1997). However, this study was conducted in the context of principal professional development, which did not consider how instructional leadership would be enacted in schools. Additional research is required at the scale of a school district and in the context of principals' work in schools to understand how school leaders' understanding of inquiry-oriented mathematics instruction can influence their problem statements and strategies they implement.

Aspects of the school and district context can shape how instructional leadership is enacted (Spillane et al.; 2004). I will consider key factors such as teachers' expertise and experience, student demographics, access to school and district coaches with expertise, relationships with principal supervisors, and accountability demands from high-stakes tests.

In my dissertation, I investigate two main orientations for improving student learning: *instructional improvement* and *instructional management*. I define orientations as being composed of both diagnostic frames and prognostic frames, or problem statements and strategies. These two orientations were observed in research conducted by members of the Middle School Mathematics and Institutional Settings of Teaching (MIST) research project (Cobb & Jackson 2011b). In the subsections to follow, I will present both instructional improvement and instructional management orientations. These illustrative cases will highlight key interrelations between diagnostic and prognostic frames, school leaders' understanding of math instruction, and contextual factors that shape instructional leadership.

Instructional Improvement Orientation

For instructional improvement orientations, school leaders frame the problem of improving student learning in relation to the quality of mathematics instruction. School leaders focus on how instruction provides opportunities for students to develop both a conceptual understanding of key content and procedural fluency. For example, diagnostic frames could identify issues relating to teachers reducing the cognitive demand of challenging math tasks (Wilhelm 2014) or teachers having insufficient Mathematical Knowledge for Teaching (MKT) to orchestrate whole-class discussions (Loewenberg Ball et al. 2008). Prognostic frames could include strategies that align with aspects of effective professional development for mathematics teachers, which are further discussed in Chapter 2.

To illustrate an instructional improvement orientation, I will use evidence from a study that investigated how to support principals as instructional leaders in mathematics (Nelson & Sassi, 2005). Nelson and Sassi (2005) studied the instructional leadership practices of an elementary school principal with a functional understanding of inquiry-oriented mathematics instruction. This principal observed that teachers often did not provide students with opportunities to develop and test mathematical conjectures, which is a key practice for students to develop (NCTM 1989, 2000). This principal developed and refined an observation tool over the course of the school year to communicate to teachers the importance of giving students opportunities to develop conjectures while learning mathematical concepts. Over time, math teachers more consistently provided students with opportunities to develop and test conjectures. Thus, through observation and feedback, this principal was able to identify a key instructional issue that limited students' opportunities to develop a conceptual understanding of mathematics. In this case, it is likely that the principal's understanding of inquiry-oriented math instruction influenced both what she looked for when observing mathematics lessons and what she valued to support teacher learning. If the principal did not understand the functions of inquiry-oriented math instruction, then it is likely that the principal would have given feedback that did not focus on a core characteristic of inquiry-oriented mathematics instruction (Rigby et al. 2017; Nelson & Sassi 2005).

Instructional Management Orientation

In contrast, school leaders could have an Instructional Management Orientation for improving student learning. In this orientation, school leaders primarily identify low student performance on procedurally-oriented assessments as a central problem to address. School leaders can use student performance on state assessments to identify where students struggle. Instructional management strategies typically reorganize current resources to improve student performance without critically analyzing the quality of mathematics instruction, prior student learning, or how instruction could have contributed to students' misconceptions. That is, such strategies do not often analyze how instruction can constrain or enable students' conceptual development. Strategies for improving student learning can include increasing instructional time by adding a second math course for low-performing students, reteaching standards with low student performance, putting teachers with high student performance in instructional leadership positions, or providing targeted-tutoring for students who were close to proficient on state assessments.

One common instructional management orientation involves identifying "bubble kids," students who are on the threshold of being proficient on state assessments, and diverting additional resources to these students (Booher-Jennings, 2005). The problem of improving student performance, here, can be framed as reaching AYP targets under the NCLB framework. School leaders and teachers identify students who are just below proficient on state assessments and then place these students in a second math class that focuses on additional practice. Importantly, this strategy does not critically analyze why students performed poorly. In addition, the strategy assumes that additional instruction will substantially improve student learning.

It is important to note that there are situations where instructional management strategies can be effective, such as when students need support in developing procedural fluency and additional practice is a straightforward way to support student learning. Furthermore, in the current era of data-driven instruction, most school leaders are expected to analyze student performance data effectively to improve test scores. Thus, it is very likely that principals will use student performance data to some extent to inform their instructional leadership strategies. It is unlikely, though, that school leaders who solely implement instructional management strategies will support teachers in developing instructional practices that effectively address the CCSSM.

Research Questions

In this dissertation, I analyze school leaders' orientations for improving student learning and how these orientations relate to supporting teachers in developing inquiry-oriented instructional practices. I investigate how school leaders' understanding of mathematics instruction, operationalized as Vision of High-Quality Mathematics Instruction (VHQMI) (Munter, 2014), relate to the implementation of instructional improvement strategies. I also analyze how aspects of the school and district context shape principal instructional leadership. Much is still unknown on how principals can support teachers in developing ambitious instructional practices (Neumerski 2013). Throughout, I conjecture that principals with a functional understanding of inquiry-oriented mathematics instruction are more likely to implement instructional improvement strategies. Additionally, I intend to identify aspects of the school and district context that influence whether school leaders' understanding of inquiry-oriented mathematics instruction influences the types of strategies they implement.

1. Does a relationship exist between school leaders' depth of understanding of inquiry-oriented mathematics instruction and their orientations for improving student learning?
2. Do aspects of the school and district context influence whether a school leaders' understanding of inquiry-oriented math instruction informs the kinds of strategies they implement?

Data for this dissertation come from years three and four of the MIST Project. In this longitudinal design study, district leaders and mathematics educators collaborated to design policies to support the improvement of mathematics instruction and student learning in the middle grades. District leaders and researchers worked together to design a coherent theory of action, which included curricula aligned with inquiry-oriented math instruction, a system of supports for teachers, teacher networks, coaching, school instructional leadership, and district instructional leadership. In these districts, principals and assistant principals were central instructional leaders who were expected to communicate instructional expectations that aligned with each district's vision, observe instruction and provide feedback on mathematics instruction, and schedule time for teachers to plan lessons and evaluate evidence of student learning. Each district provided professional development and observational tools to support principals as instructional leaders. Furthermore, principals worked with their supervisors to evaluate the school's performance and identify key instructional issues and ways to support teachers. In these contexts, principals primarily used two main orientations for improving student learning: instructional improvement and instructional management.

In the chapters to follow, I will review the relevant literature on principal instructional leadership, inquiry-oriented mathematics, and key instructional leadership capabilities for supporting teacher learning. Second, I will discuss my methods for addressing the two research questions. Third, I will present and discuss findings. Last, I will discuss broader implications for instructional leadership and instructional improvement in the final chapter.

CHAPTER 2

LITERATURE REVIEW

In this section, I review the literature on how school leaders can establish conditions within their schools that can influence the quality of mathematics instruction. I first present key conditions for supporting teachers' development of inquiry-oriented mathematics instruction. Second, I discuss key principal instructional leadership functions and review research on how principals can support changes in instruction. Third, I lay out important capabilities for school leaders as instructional leaders over math and elaborate on connections with instructional leadership functions. Throughout this analysis, I take a distributed perspective on leadership activity in that leadership is constructed and constituted through ongoing interactions between leaders and followers embedded in their contexts. In particular, I will focus on principals enacting instructional leadership functions that are intended to influence student learning and teachers' instruction.

Inquiry-Oriented Mathematics Instruction

Mathematics teachers need substantial support in developing the depth of content knowledge, understanding of student thinking, and instructional practices that address student learning goals that are being called for by mathematics educators and the CCSSM (Cobb & Jackson 2011b; Loewenberg Ball et al. 2008; Jackson et al. 2012; Stein et al. 1996; Fennema et al. 1996; Stigler & Hiebert 2009). In most US math classrooms, teachers first present procedures for particular types of tasks and then monitor student work for the accurate reproduction of these procedures (Stigler & Hiebert, 1999). In contrast, inquiry-oriented mathematics classes typically start with teachers building a shared understanding of mathematical relationships and contextual features of a cognitively demanding task (Jackson et al. 2012), then pressing students as they collaborate in groups to construct their solutions (Boaler & Humphreys 2005; Franke et al. 2007), and finally orchestrating a concluding whole-class discussion in which teachers organize various student solutions in order of mathematical sophistication (Stein et al. 2008). In inquiry-oriented mathematics instruction, common aspects of mathematics tasks include generalizing solutions from patterns, forming mathematical arguments, evaluating the reasonableness of solutions, and making connections between different mathematical representations and different solution strategies (Stein et al. 1996; Boaler & Humphreys 2005; Stein et al. 2008). Between the two modal forms of mathematics instruction, there are key differences in relation to what is considered to be a cognitively demanding task, the role that the teacher plays in facilitating student learning, and the structure and nature of discourse in the classroom (Munter 2014; Franke et al. 2007).

To support the improvement of teaching, mathematics educators have outlined student learning goals and instructional practices (NCTM, 1989, 2000). Recently, the majority of states have adopted the CCSSM (2010), which specifies content and practice standards for student learning that are similar to standards specified by NCTM. Both sets of student learning goals place emphasis on developing a conceptual understanding of central content across several domains as well as developing procedural fluency. Additionally, students are expected to develop increasingly sophisticated forms of mathematical argumentation as they participate in small-group and whole-class discussions (NCTM, 2000). Furthermore, these standards call for equitable learning opportunities in mathematics for all students (Lampert & Graziani, 2009; NCTM, 2000).

Mathematics educators have investigated instructional practices aligned with these student learning goals (Hiebert & others 1997; Kazemi et al. 2009; Stein et al. 2008; Lampert 1990). Key instructional practices include selecting cognitively demanding math tasks (Stein et al. 1996), launching tasks to support all students in understanding the contextual features and mathematical relationships in the task (Jackson et al. 2012), supporting groups of students as they work towards constructing a solution, and orchestrating concluding whole-class discussions in which teachers scaffold student solutions in order of mathematical sophistication (Gibbons 2012; Stein et al. 2008). These practices have been termed as ambitious because teachers have to anticipate and respond to student thinking on cognitively demanding tasks in real time (Cohen 2011). Inquiry-oriented mathematics instruction differs from traditional mathematics instruction on several key points. For traditional mathematics instruction, the range of student responses has been narrowed by the teacher through careful sequencing of tasks and demonstrating key components of mathematical algorithms. Ambitious instruction requires a deep understanding of the mathematical content, an understanding of the various ways in which students solve tasks for a given topic, an understanding of what students currently know and can do, an understanding of the sources of common errors that students make for that content, and the ability to anticipate and sequence solution strategies for whole-class discussions to show a range of mathematical approaches (Ball et al., 2008; Silver & Stein, 1996). Making the transition from traditional US mathematics instruction to inquiry-oriented mathematics instruction is non-trivial and requires substantial teacher learning.

Research on teacher learning, professional development, and teacher education has identified several characteristics of professional development that can support teachers in both deepening mathematical knowledge for teaching and developing high-leverage instructional practices (Ball et al. 2009; Wilson 2015). Foundational is that teachers are led by educators who have developed target practices, who have the capacity to identify goals for individual teachers and groups of teachers, and are able to select and enact activities that support teacher learning (Carpenter et al. 2000; Kazemi & Franke 2004; Jackson & Cobb 2013; Ball et al. 2009; Wilson 2015). Other important features include a focus on a core set of high-leverage instructional practices (Ball et al. 2009); frequent, intensive professional development on high-leverage practices that is sustained for multiple years (Borko 2004; Fennema et al. 1996; Gibbons 2012); learning events that incorporate current instructional materials and directly address instructional problems (Silver & Stein, 1996); opportunities for teachers to analyze representations of practice and rehearse target instructional practices (Kazemi et al. 2009; Kazemi et al. 2009; Grossman et al. 2009); and coordination of professional development across contexts and across role groups (Jackson & Cobb 2013). Furthermore, it is important that groups of teachers are supported in developing communities of professional practice that provide opportunities for collective analysis of instruction and student learning (Jackson & Cobb 2013; Horn & Little 2010; Darling-Hammond et al. 2009). This vision of professional development is in contrast to typical professional development that teachers participate in, which is typically discrete, disconnected, and diffuse in focus (Borko 2004; Ball & Cohen 1999). Supporting teachers in reorganizing their instructional practices also requires that district leaders, school leaders, and coaches reorganize and coordinate their instructional leadership practices. Thus, supporting significant teacher learning also requires substantial organizational learning and redesign (Jackson & Cobb 2013).

It is important to keep in mind that there are also some school level and district level factors that can influence and mediate the influence of high-quality PD (Cobb et al. 2003; Gamoran

2003). The structure of the school day, school size, working relationships with colleagues, access to colleagues with sophisticated instructional practices, and accountability pressures might also shape both how teachers plan for instruction and their instructional practices, independent of the quality of professional development teachers receive. Additionally, the capacities of district and school leaders as well as their beliefs about student learning shape opportunities for teachers' learning (Coburn & Russell 2008; Stein & Coburn 2008; Spillane & Thompson 1997; Cobb et al. 2003; Spillane & in Education 2000). Turnover in personnel, shifts in policies over time, and shifts in instructional tools can also disrupt sustained improvements in teaching in schools and school districts (Gamoran, 2003; Silver & Stein, 1996).

Principal Instructional Leadership and Relationships with Improving the Quality of Instruction

To understand how principal instructional leadership can influence the quality of mathematics instruction and instruction in general, I conducted a literature review and synthesized findings from twenty-nine studies. I divided the relevant studies into two categories: Professional Community Studies (9 Studies), and Policy Implementation Studies (20 Studies).

Professional Community studies primarily used quantitative methods to investigate relationships between principal instructional leadership, instructional vision, aspects of the school culture, and teachers' instructional practices (Sebastian & Allensworth 2012; Wahlstrom & Louis 2008; Printy 2008; Marks & Printy 2003; Printy 2008). Findings from the Professional Community studies consistently indicated that effective principals were often in schools with a shared instructional vision, high levels of relational trust, high levels of shared leadership, high expectations for student learning and instruction, shared commitments for improving student learning, and teacher collaboration that focused on planning and sharing resources.

Overall, these studies did not make clear connections between goals for improving student learning and instruction, principals' practices, and instructional improvement. In the absence of such connections, it is unclear how principal instructional leadership related to instructional improvement. Additionally, eight of the nine studies in this category used self-report measures for classroom instruction. Self-report measures can be invalid, particularly when these measures assess complex instructional practices (Dunlap et al., 2015). One key issue of self-report measures is that key terms and phrases used to describe teaching have a range of different meanings for practitioners and researchers (e.g. rigor); survey methodologies are unable to determine how participants understood survey items. Furthermore, prior research indicates that practitioners might not accurately assess changes in their instruction when learning new, unfamiliar instructional practices (Spillane & in Education 2000; Cohen 1990). Thus, findings from Professional Community studies provide a constellation of contemporaneous characteristics of schools (e.g. high expectations for student learning, relational trust, shared leadership), but no clear indication on how principal instructional leadership related to instructional change.

Findings from the Policy Implementation studies point to the importance of instructional leaders communicating a coherent set of goals for student learning and instructional practices (Graczewski et al. 2009). Effective principals align professional development activities (Youngs & King 2002) and the work of instructional coaches with these goals (Higgins & Bonne 2011). Additionally, instructional change is a process that requires multiple years of sustained, coherent support (Higgins & Bonne 2011; Graczewski et al. 2009; Youngs & King 2002). Furthermore, principals who were more frequently involved in instructional leadership activities were better positioned to identify central issues of instruction and broker opportunities for content-specific professional development or content-focused coaching (Gibbons 2012; Burch & Spillane 2003;

Graczewski et al. 2009). In conclusion, effective principals can work with staff to define shared improvement goals, can align supports with these goals, and need to be involved instructional leaders who understand the problems teachers encounter and have strategies for supporting teacher learning.

Several of the Policy Implementation studies also found that effective configurations of instructional leadership involved principals and coaches fulfilling different and complementary roles (Gibbons 2012; Higgins & Bonne 2011; Burch & Spillane 2003; Mangin 2007). For example, principals typically evaluate teachers, have considerable influence over the design and organization of the school, and have authority over matters relating to the school budget, hiring, and procuring resources external to the school. While instructional coaches typically provide ongoing content-specific professional development for both individual teachers and groups of teachers (Gibbons 2012; Higgins & Bonne 2011; Burch & Spillane 2003). There can be a synergistic effect when principals and coaches fulfill complementary roles and have congruent instructional visions (Gibbons 2012; Higgins & Bonne 2011). That is, principals and coaches can collaborate to both redesign the organizational structure of the school and provide intensive and coherent support for teachers.

Importantly, though, changes in instruction that were reported in Policy Implementation studies were not congruent with those required for ambitious instruction (Huggins et al. 2011; Higgins & Bonne 2011; Timperley 2005). In one study, Huggins et al. (2011) presented a discussion from a teacher collaborative meeting where teachers shared strategies for finding the y-intercept. In the example, one teacher covered up a line around the y-axis to demonstrate how this skill can be taught visually, which does not help students learn key concepts on linear functions. For example, it is important for students to learn what it means when the input has a value of zero, particularly for mathematical models of real-world phenomena. Although teachers can learn more tips and tricks when sharing simple strategies, such instruction does not support students in developing a robust understanding of mathematical concepts. In summary, Policy Implementation studies illustrated how principals could implement policies to influence instructional change, it was still unclear if/how teachers substantially reorganized their practice, particularly in relation to ambitious goals for instruction.

Summary. In sum, findings from both sets of studies highlight the importance of four key instructional leadership functions: developing and sustaining shared goals for student learning and instruction, brokering learning opportunities aligned with goals, fostering teacher collaboration, and monitoring student learning and instruction. Table 1 summarizes findings by instructional leadership function, instructional leadership tasks within each function, and outcomes. Findings in this table highlight how little is understood on how principals can support teachers in developing ambitious instructional practices.

Table 1

Instructional Leadership Functions, Instructional Leadership Tasks, and Outcomes

Instructional Leadership Functions	**Instructional Leadership Tasks**	**Outcomes**
Developing and Sustaining an Instructional Vision	Work with staff to identify goals for student learning and instruction (Graczewski et al. 2009; Youngs & King 2002; Fletcher et al. 2013; Higgins & Bonne 2011; Datnow & Castellano 2001; Kurland et al. 2010; Huggins et al. 2011; McGhee & Lew 2007; Burch & Spillane 2003; Timperley 2005; Marks & Printy 2003)	Staff can come to a consensus on goals for instruction, which can serve as foundation for coherent professional development (Graczewski et al. 2009), identify those with relevant expertise (Higgins & Bonne, 2011), highlight key activities for teacher collaboration (Youngs & King, 2002), and highlight ways of monitoring

		instruction and student learning (Nelson & Sassi, 2005)
	Interact with teachers to continually communicate expectations and goals for student learning and instruction (Katterfeld 2013; Coburn 2005; Coburn & Russell 2008; Manouchehri & Goodman 1998)	Teachers understand key performance outcomes. Certain policy messages can be shut out, while others promoted (Coburn 2005). Strong influence over the implementation of reform curricula and new ways of thinking about instruction (Manouchehri & Goodman, 1998). Strong influence over how teachers perceive and use new instructional tools (Coburn & Russell, 2008).
	Sustain support around instructional vision for multiple years (Manouchehri & Goodman 1998; Graczewski et al. 2009; Youngs & King 2002; Higgins & Bonne 2011)	Greater likelihood of policy implementation and instructional change (Graczewski et al., 2009), greater likelihood of sustained, coherent PD (Graczewski et al., 2009; Higgins and Bonne, 2011; Youngs & King, 2002)
Brokering Learning Opportunities	Ensure PD is coherent, sustained aligned with goals for student learning and instruction (Graczewski et al. 2009; Youngs & King 2002; Fletcher et al. 2013; Higgins & Bonne 2011; Datnow & Castellano 2001; Higgins & Bonne 2011; Sebastian & Allensworth 2012)	Associated with higher levels of teacher reports on critical thinking and discourse (Sebastian & Allensworth 2012) and gains knowledge, skills, and dispositions in SFA (Youngs & King 2002)
	Identify, support, and meet instructional coaches, teacher leaders, those with expertise to provide ongoing support for teachers (Gibbons 2012; Higgins & Bonne 2011; Mangin 2007)	Teachers have opportunities to work with those with expertise on goals for instruction (Higgins & Bonne 2011); More teachers seek out coach (Gibbons 2012)
	Bring in content-based PD focused on developing planning, instruction, and assessment practices (Graczewski et al. 2009; Burch & Spillane 2003; McGhee	Teachers feel more supported(McGhee & Lew 2007); teachers more likely to change instructional

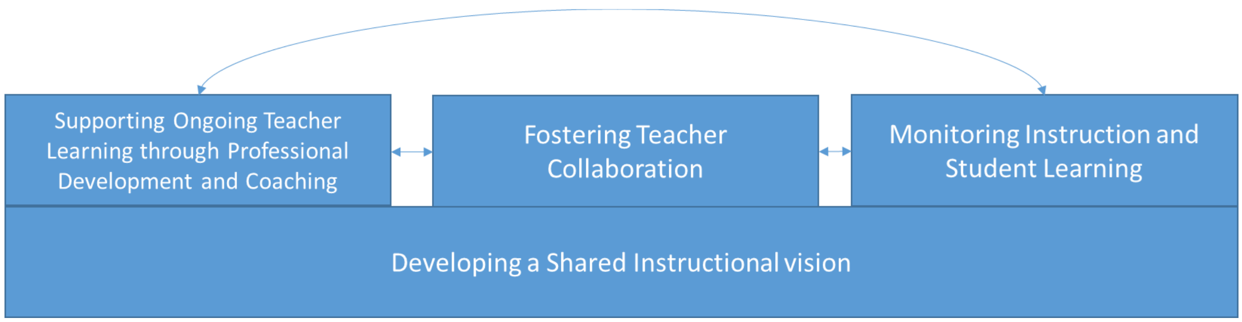
	& Lew 2007; Fletcher et al. 2013; Timperley 2005; Mangin 2007)	practices along policy lines (Graczewski et al., 2009)
Fostering Teacher Collaboration	Build in time and re-organize resources to schedule time for teacher collaboration, decide who participates, and decide who facilitates (Coburn 2005; Manouchehri & Goodman 1998)	Helps teachers make sense of new instructional policies and how this influences instruction and assessment of student learning (Coburn, 2005). Helps teachers implement new policies (Coburn 2005; Manouchehri & Goodman 1998)
	Communicate Expectations for activities conducted during Collaboration (Blanc et al. 2010; Coburn 2005; Graczewski et al. 2009; Huggins et al. 2011; Timperley 2005; Youngs & King 2002)	Can Influence teachers to share instructional strategies (Huggins et al. 2011), identify students for intervention (Blanc et al. 2010), and can influence the quality of assessments that teachers use (Timperley, 2005)
Monitoring the Quality of Instruction and Student Learning	Consistent feedback to teachers based on tasks and task implementation (Nelson and Sassi, 2005)	Can influence the math tasks that teachers select for students and how they guide students' work on those tasks (Nelson and Sassi, 2005)
	Monitor instruction, attend meetings, and interact with teachers and instructional leaders to identify content-specific support for teachers (Burch & Spillane 2003; Graczewski et al. 2009; Timperley 2005; Timperley 2005; Mangin 2007; Gibbons 2012; Blase & Blase 2000)	School leaders are better positioned to identify goals for improving student learning and instructional improvement (Burch & Spillane, 2003). Better positioned to bring in content-specific support for teachers and improve instruction (Graczewski et al. 2009). A better understanding of who has expertise, which could inform who facilitates teacher collaboration, who coaches teachers, and what activities take place during teacher collaboration (Timperley, 2005; Burch &

		Spillane, 2003; Gibbons, 2012; Mangin, 2007).
	Regularly provide feedback to promote teacher reflection and professional growth (Blase & Blase 2000; Ing 2010)	Teachers have a better understanding of how to improve student learning and instructional practices generally (Blase and Blase, 2000). Greater levels of teacher collaboration and shared commitments to student learning in schools where feedback is given as a means of PD rather than evaluation (Ing, 2010).

It is important to point out interconnections between these instructional leadership functions (refer to Figure 1). For example, establishing goals for student learning and instruction helps define learning goals for teachers and can guide the content and activities of professional development (Coburn 2006). Furthermore, goals for improving instruction and student learning shape the activities enacted by groups of teachers when they collaborate. Given the importance of expertise in facilitating learning for mathematics teachers (Wilson, 2015), this then has implications for who facilitates both teacher collaboration and professional development. Also, goals for student learning and teacher learning influence what principals, instructional coaches, and teachers look for when observing instruction and analyzing student work or performance data. Additionally, all of the relationships between these instructional leadership functions are bi-directional. For example, through monitoring instruction, school leaders might identify new instructional issues, which could then reshape goals for teacher learning, which in turn can influence the content of professional development as well as the goals for teacher collaboration. Also, if teachers develop ambitious instructional practices as a result of participating in ongoing learning events, then this can then lead to defining new goals for improving teacher learning (Higgins & Bonne 2011; Youngs & King 2002; Graczewski et al. 2009).

Figure 1

Interdependencies between various instructional leadership functions



Findings from the Professional Community studies and Policy Implementation studies have several implications for what principals need to know and do to support teachers' development of inquiry-oriented instructional practices. School leaders will need to collaborate with teachers and instructional leaders who have relevant expertise to establish shared goals for improving student learning and instruction in ways that are aligned with inquiry-oriented mathematics. Additionally, I conjecture that it is essential for principals to identify high-quality enactments of inquiry-oriented mathematics instruction. That is, principals need to be able to identify key instructional moves as well as student moves to understand that instruction is supporting students in developing a conceptual understanding of mathematics as well as developing practices that are important for representing mathematics and communicating their work. Third, principals need to be able to work with teachers and coaches to ensure that professional development provides opportunities for both individual teachers and groups of teachers to develop inquiry-instructional practices. Fourth, it is important to align the goals and activities of professional development and teacher collaboration with the goals for improving student learning and instruction.

Principal Instructional Leadership Capabilities

In addition to principal instructional leadership functions, it is also important to consider the capabilities needed to enact these functions (Robinson 2010; Neumerski 2013). That is, researchers do not have an understanding of what principals need to know, do, and be to effect instructional change. This gap exists in the field in part because many researchers have not taken a stance on important student learning goals and important instructional practices, which then obfuscates what effective instructional leaders need to do to support teacher learning. By developing an understanding of important instructional leadership capabilities, researchers can identify key instructional leadership practices as well as understand how to support instructional leaders in developing these practices. For my dissertation, I will use inquiry-oriented mathematics as the goals student learning and goals for instructional practices. Thus, principals who are effective in this context will have some degree of understanding of inquiry-oriented mathematics instruction as well as understand the challenges that teachers face when developing these practices.

Robinson (2010) presents three interconnected capabilities that have been directly or indirectly associated with improved student learning outcomes: Solving Complex Problems, Leadership Content Knowledge (LCK), and building relational trust. I focus on the first two capabilities for my dissertation.[1] In the following sections, I first discuss how problem-solving

[1] Ideally, I would have incorporated measures of trust into my dissertation, but these measures were not available for the data I analyzed. As an aside, relational trust has been associated with improvements in student achievement, teachers feeling more supported in their work, greater levels of teacher collaboration, and greater levels of collective commitment for improving student learning (Bryk & Schneider 2002).

has been studied in relation to instructional leadership. Then, I discuss LCK and its relevance to my study. Refer to Table 2 below for a summary of important capabilities and aspects of those capabilities.

Table 2

Key Instructional Leadership Capabilities and Important Aspects of those Capabilities

Capabilities	Aspects
Leadership Content Knowledge	Assess quality of instruction to understand who has expertise, who needs support, and to identify instructional issues
	Identify instructional leaders who can support teacher learning directly.
Problem-Solving	Identify key problems of student learning and instruction, build consensus around identified problem, build consensus around student learning goals and instructional improvement goals, and co-develop strategies for solving problems
	Strategically managing resources and maintaining focus on group goals
Relational Trust	Establish trusting relationships between teachers, coaches, and school leaders
	Leverage position as evaluator judiciously and in ways that are aligned with the main goals of the school.
	Buffer teachers from extraneous work or from work that can distract from focal goals

Solving Complex Problems. The nature of the problems that school leaders and teachers face are complex and ill-specified (Robinson, 2010). Jonassen (1997) states that ill-specified problems: "… problems possess multiple solutions, solution paths, fewer parameters which are less manipulable, and contain uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized and which solution is best (p. 65)." Additionally, ill-specified problems are situated and emergent within contexts, involve both surface-level issues and fundamental, underlying issues, and are encountered by practitioners daily. Identification of a problem does not inherently provide sufficient information on how to solve the problem. Key factors for solving ill-specified problems of instructional leadership considering multiple perspectives and clarifying assumptions from teachers and coaches, connecting strategies for improvement to identified problems, considering constraints inherent in context and limitations of strategies, reaching a broad consensus on viability of strategies, implementing and monitoring strategies, and adapting strategies as problems evolve (Robinson 2010; Jonassen 1997; Leithwood & Steinbach 1995).

By definition, the problems of improving the quality of student learning and instruction are ill-specified. A school leader tasked with improving the quality of mathematics instruction is engaging with a vaguely specified problem that has multiple problems to be addressed, and each problem has both surface level aspects as well as deeper issues. Furthermore, by identifying key problems, principals can implement multiple strategies; however, it is unclear how these strategies will pan out or if there were various constraints that were not considered. For example, a principal might identify a surface level issue of teachers proceduralizing cognitively-demanding math tasks; however, this does not specify how to support teacher learning nor indicate what might be the deeper underlying issue. The deeper underlying issue could be that teachers view inquiry-oriented mathematics instruction as inappropriate for their students, which could be further entrenched if teachers are evaluated based on student performance on procedurally-oriented state assessments. If a principal brokers PD that focuses on maintaining the cognitive demand of tasks, it might not lead to substantive changes in teachers' instruction if teachers are more concerned about performing student performance and don't see how the training is pertinent.

Leadership Content Knowledge. Stein and Nelson (2003) define LCK as:

> The kind of knowledge that will equip administrators to be strong instructional leaders we will call leadership content knowledge. Standing at the intersection of subject matter knowledge and the practices that define leadership, this form of knowledge would be the special province of principals, superintendents, and other administrators charged with the improvement of teaching and learning. P. 424

In addition, school leaders will need to understand, to some degree, how students learn in a particular content area, how teachers can effectively influence student learning, how to identify common instructional issues, and how to support teacher learning.

Small-scale studies have found a relationship between school leaders' LCK and their diagnostic and prognostic frames (Nelson 1997; Nelson & Sassi 2005). These studies indicate that school leaders with a functional understanding of inquiry-oriented math instruction are more likely to identify key instructional issues when observing inquiry-math classrooms, such as students not having adequate opportunities to explore concepts and test conjectures (Nelson & Sassi 2005). This is in contrast to school leaders who primarily attend to surface-level features of instruction (e.g. students working in groups) without also attuning to how the teacher supports students in deeply understanding the content.

There are two key constraints in the Nelson and Sassi (2005) study to consider. First, principals in the Nelson and Sassi study were expected to support teacher learning directly and participated in atypical amounts of training. It is unlikely that most school districts will have such expectations for principals as instructional leaders. Additionally, when considering the scope of principals' work (e.g. administrative, managerial, organizational, instructional, etc.), it is unlikely that most school districts would invest in monthly, all-day principal professional development that focuses on instructional leadership in one content area. Second, Nelson and Sassi (2005) were working with principals at the elementary school level. As the school level increases and as departments become more siloed, it is less likely that school leaders at scale will have the capacity and time to support math teachers directly. Given that the MIST study investigates instructional improvement at the middle school level, it is very likely that only a few principals had the capacity to support teacher learning directly.

In the context of professional development, Nelson (1998) found that principals who understood the underlying functions of inquiry-oriented mathematics instruction were also more likely to consider effective strategies for supporting teacher learning. For example, principals who had a functional understanding were more likely to view position professional development as a key strategy for supporting teacher learning. These principals also reported that it was important for PD to be led by teachers who had developed both ambitious instructional practices and the capacity to challenge teachers' beliefs about mathematics instruction and how students learn. This is in contrast to principals who had a form-level understanding of inquiry-oriented math instruction. These principals did not take into account the learning demands put on teachers when developing ambitious instructional practices. Principals with a form-understanding valued professional development that would help teachers "update" their current instructional practices. Importantly, several studies have found that teacher learning is unlikely to occur without developing norms on productively challenging beliefs around instruction and student learning (Grossman 2001; Horn & Little 2010; Kazemi & Franke 2004). That is, professional development and learning events that focus on "updating" practices are unlikely to change teachers' deeply held and often self-confirming beliefs about teaching and student learning (Lortie 1975; Lampert 2012). It is important to consider that the study conducted by Nelson (1998) occurred in the context of professional development and not in school settings. Similar to research on teacher professional development, learning in the context of professional development does not directly lead to changes in school contexts.

It is also important to consider the complexity of principals' jobs and the many different tasks they perform. One study conducted in a large urban school district estimated that elementary and secondary principals spent about 15% of their time on instructional leadership activities in a given school day, which is approximately one hour in a seven-hour school day (Horng et al. 2010). Given these institutional constraints, I conjecture that principals are more likely to impact instruction through fostering shared goals and strategies and maintaining focus on these goals and strategies rather than one-on-one instructional leadership activities with teachers. This conjecture places considerable importance on the availability of those with expertise in mathematics in schools as well as district leaders' expectations for student performance and instructional quality. Without appropriate support and accountability, it is unlikely that principals will be able to support instructional improvement (Elmore 2000).

CHAPTER 3

METHODOLOGY

For my dissertation, I investigated how school leaders framed the problem of improving mathematics instruction and student learning, which strategies they implemented, and how aspects of the school and district context influenced instructional leadership. To address my first research question, I used statistical analyses to identify if there was a relationship between a school leaders' understanding of inquiry-oriented math instruction and the implementation of instructional improvement strategies. To do this, I coded principal interview data from Years 3 and 4 of the MIST study to code diagnostic frames and prognostic frames. Then, I conducted statistical tests and regression analyses to test for relationships between measurements of school leaders' understanding of inquiry mathematics and implementation of strategies that had the potential to support instructional improvement.

For my second research question, I selected four sets of cases, or groups, to assess how aspects of the school and district context influenced school leaders' problems and strategies for improving mathematics instruction. The four groups were formed based on Function/Form VHQMI and implementation of improvement or management strategies. For the second research question, I made memos for each case-study school and tested conjectures within groups and across groups to understand how aspects of the school and district context influenced principal instructional leadership.

In the following sections, I first discuss the context of the research. Then, I will present the data and analyses for the first research question. Third, I will discuss the case selection processes. Last, I will present the data and methods used to address the second research question.

Research Context

During the first four years of the MIST study, the research team engaged in design research with district leaders located in four large urban school districts to improve the quality of mathematics instruction in ways that are compatible with the CCSSM [cobb2008district cobb2011towards]. Each school year, the sample included approximately 60 district leaders, 30 schools, 30-50 principals and assistant principals, 120 teachers, and approximately 30 math coaches. During the fall of each study year, research team members interviewed various district leaders across Curriculum and Instruction and Leadership Departments to determine the main planks in each district's Theory of Action (ToA) for improving mathematics instruction. During the spring, the research team conducted interviews with district leaders, school leaders, teachers, and mathematics coaches to determine how each district's ToA was being implemented in middle schools. Findings and recommendations for each district were summarized in the District Feedback and Recommendation Reports (DFRRs). The research team also collected surveys from principals, teachers, and coaches; video-recorded two lessons from each teacher; collected instructional advice-seeking network surveys; and assessed the Mathematical Knowledge for Teaching (MKT) of all full-participant teachers and coaches (Ball et al. 2009). For my dissertation, I used principal interviews, ToAs, DFRRs, data from teacher and principal surveys, School Summary Forms (SSFs), and measures of expertise (e.g. VHQMI, MKT, IQA) from all full participants within a school.

Expectations and Supports for School Leaders

In all four districts, principals were expected to press and support teachers in learning how to enact inquiry-oriented mathematics instruction. Consistently, school leaders were expected to: 1) communicate expectations to teachers aligned with inquiry-oriented mathematics instruction, 2) informally observe mathematics teachers and provide feedback that supported instructional improvement, and 3) provide time in the school schedule for math teachers to meet. Expectations for school leaders varied across districts (Refer to Table 3). District B had the most extensive expectations for school leaders as instructional leaders.

All four districts provided both tools and professional development to support school leaders as instructional leaders (see Table 4). It is important to note that the majority of tools and training provided by all four districts were not specific to mathematics instruction, which is unlikely to support school leaders in being effective instructional leaders over inquiry-oriented mathematics (Nelson & Sassi 2000). In addition to training in instructional leadership, principals and assistant principals had monthly professional development over a range of pertinent issues for school leaders (e.g. managerial, organizational, financial, etc.). With the exception of the MIST Principal PD in District D in Year 3 (Boston et al. 2016), the majority of principal professional development sessions did not focus on developing instructional leadership practices in mathematics. The MIST Principal PD consisted of three monthly PD sessions that focused on identifying cognitively-demanding tasks, identifying key aspects of inquiry-math instruction, and critiquing videos of mathematics instruction. This study found that principals were better able to identify low-level math tasks and increased their VHQMI within the context of professional development (Boston et al. 2016). Of interest for this study is whether this training supported principals in both identifying problems central to inquiry-oriented mathematics instruction and implementing instructional improvement strategies.

Table 3

Principal Instructional Leadership Expectations by District

Description of Policy	District A	District B	District C	District D
Communicate instructional expectations aligned with high-quality mathematics instruction	✓	✓	✓	✓
Informally observe mathematics teachers and provide feedback that supports instructional improvement	✓	✓	✓	✓
Provide time in the school schedule for mathematics teachers to meet	✓	✓	✓	✓
Attend teacher collaborative time	✓	✓		
Collaborate with school or district math coaches or department heads		✓	✓	✓
Either principal or an assistant principal can evaluate and support math department		✓		✓
Use data to assess effectiveness of instruction		✓		

Sample Selection

To address my research questions, I used data from Year 3 and Year 4 of the MIST Study. I started the sample selection process by randomly coding principal interviews from Years 1 through 5 of the MIST study to understand how principals framed the problem of improving student learning in mathematics. The MIST Study conducted research with four school districts during the first four years of the study (District A – District D) and then continued with two districts for the next four years of the study (District B and District D). For sample selection, I did not include data from Year 1 and Year 2 of the study because school leaders were missing VHQMI data at greater rates, which made it more difficult to assess school leaders' understanding of inquiry-oriented mathematics instruction.

I also did not include Year 5 for analysis because student learning goals and high-stakes state assessments shifted in both District B and District D. These shifts resulted in principals being less certain about the effectiveness of their instructional leadership. District B is in a state that transitioned to a more conceptually-rigorous state assessment in Year 5. District D is located in a state that adopted the CCSS-M. As a result of the adoption of the CCSS-M, several standards were moved to lower grade levels, and teachers in District D needed to supplement the district curriculum, Connected Mathematics Project 2 (CMP2), with additional resources. In contrast to prior years, school leaders in District D focused on ensuring that teachers had instructional materials that addressed the content on the new state assessments. In both districts, there was evidence from school leader interviews that principals were less certain about the district vision and goals for improving mathematics instruction, and consequently were less certain on how to support teachers. Furthermore, in both districts, there was evidence that a greater proportion of principals relied solely on instructional management strategies, possibly in response to dealing with the uncertainty of how to respond to new standards and assessments. In contrast, evidence from school leader interviews indicated that school leaders in Year 3 and Year 4 had a more in-depth understanding of the district vision and district goals, which also corresponded with more certainty on how to support teachers. As a result, I included data from Year 3 and Year 4 for my analysis.

After selecting which study years to focus on, I then selected principals to include in my analysis. I retained either principals or assistant principals who primarily oversaw the mathematics department. In some schools, I retained multiple school leaders because each leader had different responsibilities for evaluating and supporting math teachers. For example, in one school, the principal evaluated 6th-grade math teachers, and the assistant principal evaluates 7th- and 8th-grade math teachers. As a result, I included seventy-one school leaders in my analyses.

Table 4

Supports and Tools for School Leaders as Instructional Leaders in Mathematics

Type of Support	**Year**	**District A**	**District B**	**District C**	**District D**
PD for Principals	3	Two sessions for Ps at monthly meeting to train principals on using math-specific observation tool	One session to familiarize Ps with scope and sequence and to familiarize Ps with phases of CMP2 lesson.	Four sessions for Ps throughout the year on Academic Rigor and Accountable Talk, time split for math and science	Three sessions for school leaders provided by Vanderbilt and Pitt on identifying rigorous tasks, identifying high-quality enactment of tasks, and rehearsals of giving feedback
	4	Five sessions for APs on observing the CMP2 lesson	Regular PD for APs on changes in new state assessment to be implemented in Y5, lesson plan format and CMP2 lesson structure, and instructional coaching.	One session on formative assessment in mathematics	One optional session in which a minority of school leaders attended.
Observational Tools	3&4	Observation tool that aligned with the format of a Connected Mathematics Project 2 Lesson: Launch, Explore, Summarize. Tool has both categorical ratings and spaces for writing in feedback	Content Theme Maps – summary of scope and sequence over six week period and what to look for as evidence of student learning		Observation tool that included descriptions of rigorous math tasks that aligned with the Instructional Quality Assessment (Matsumura et al., 2008)

Data for Research Question 1

RQ1: Does a relationship exist between school leaders' depth of understanding of mathematics instruction (i.e. VHQMI) and their orientations for improving student learning?

Principal Interview Data. To understand principals' problem statements and strategies, I analyzed school leaders' responses to questions that focused on the participants' background, organization of mathematics teaching, goals for mathematics instruction, strategies for improving student learning, and challenges that school leaders face when improving mathematics instruction (See Appendix A). These interview questions were consistent across districts for both Year 3 and Year 4. In each school, the MIST team interviewed the principal and any assistant principal who oversaw the mathematics department. For my dissertation, I primarily considered the school leader who monitored all mathematics teachers. If there were multiple school leaders who supported and evaluated math teachers, then I coded all relevant school leader interviews.

The principal interview transcript contains the turn-by-turn account of the interview and also included time stamps as well as notes about breaks in the interview (e.g. announcement comes on over the school PA). The transcript is not annotated with interviewer notes; however, interviewers could make additional notes in the principal ISF if they chose to do so. The principal ISF is a summary of the principal interview that was completed in the field by the interviewer or another research team member. The ISFs summarize key aspects of the district, organization of teaching, principal VHQMI, teacher collaboration, observation and feedback, school professional development, principal professional development, relationships with principal supervisor and accountability demands, and principal networks. I used the principal ISFs to ensure that I was not over-interpreting the data and to ensure that I had not missed key aspects of the school and district context from the principal interview.

Vision of High-Quality Mathematics Instruction. I used the interview-based VHQMI rubrics (Munter 2014) to assess school leaders' understanding of inquiry-oriented mathematics instruction. These rubrics were used by MIST research team members to code participants' descriptions of a high-quality mathematics lesson. See Appendix B for both the interview protocol and a description of all eight VHQMI rubrics. The central interview question asked participants to describe what they would expect to see if they observed a high-quality mathematics lesson. The protocol includes specific probes for the Role of the Teacher (RT), Patterns and Structure of Discourse (PS), the Nature of Talk in the classroom (NT), and aspects of high-quality Math Tasks (MT). Each of the eight rubrics has an ordinal range of values, typically from a score of 1 to a score of 4. Scores are ordered based on an understanding of inquiry-oriented math instruction. A score of 1 typically represents a more traditional view for that dimension of mathematics instruction (e.g. IRE discourse for the PS rubric) and a score of 4 typically represents a functional understanding for that dimension (e.g. whole-class discussion in which multiple groups of students present various solutions and groups press each other on the validity of strategies for the PS rubric).

For each school leader, I considered their VHQMI scores for the Role of Teacher (RT), Nature of Talk (NT), Patterns and Structure of discourse (PS), Math Tasks (MT), Teacher Questions (TQ), Student Questions (SQ), and Student Explanations (SE). I did not include the CA rubric for this analysis because it is on a different scale that doesn't contain the form-function distinction. It is important to note here that the VHMQI rubrics are not orthogonal and independent from each other. Thus, understanding aspects of the Nature of Talk in inquiry-oriented mathematics also has implications for the Patterns and Structure of Discourse as well as the Role of the Teacher in the lesson. For example, if you state that it is important for students to talk about the math task together in groups and press on each others' reasoning, then this has implications for discourse structures (PS), what students are talking about (NT), and how the teacher orchestrates these interactions (RT).

For my dissertation, I primarily used the Function VHQMI measurement to assess principals' understanding of inquiry-oriented mathematics instruction.[2] The Function VHQMI measurement classified principals based on whether or not they demonstrated a functional understanding of a particular VHQMI dimension. Principals were categorized as Function VHQMI if they received a four on any of the main seven rubrics: PS, RT, MT, NT, TQ, SQ, and SE. Otherwise, principals were categorized as having a Form VHQMI. I conjectured that school leaders with a Function VHQMI were more likely to identify key aspects of inquiry-oriented mathematics instruction and implement strategies for improving instruction (Stein & Nelson 2003; Nelson & Sassi 2005). Additionally, I conjecture that school leaders with a functional understanding of inquiry-math instruction have a greater capacity to both identify key instructional issues that relate to inquiry math and also design and implement strategies that address these instructional issues.

Analysis for Research Question 1

Developing the codebook. I coded a set of questions from school leaders' interviews to understand how they framed the problem of improving student learning in mathematics and which strategies they implemented to support student learning. Throughout the coding process, I used both a priori codes and emergent codes (Charmaz, 2000, p. 46). Coding of the seventy-one

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[2] I also ran a series of analyses using a mean VHQMI measurement – a measurement generated by taking the mean of all eight VHQMI dimensions. Results for RQ1 were similar for both the Function and Mean VHQMI measurements. I decided to only report on Function VHQMI because it was important for case selection and for analysis for the second research question.

school leader interviews occurred in two phases: descriptive and analytical. In the descriptive phase, I coded principal reports in ways that were close to participant descriptions to understand how school leaders described their work as instructional leaders. For example, if a principal described using a second math class to support skill development for low-performing students, this received a code: Additional Math Class – Skill Development. For analytical coding, I regrouped a subset of the descriptive codes into analytical categories based on the instructional leadership functions described previously in this dissertation. One of the key reasons for the second round of coding was to categorize problems and strategies in relation to their alignment and potential for improving inquiry-oriented math instruction. To build on the previous example, adding a second math class to support basic skills was coded as an instructional management strategy under the Monitoring and Supporting Student Learning Instructional Leadership Function because the strategy reorganizes how resources are used in the school without pressing teachers to substantially reorganize their instructional practices. In the sections to follow, I describe the descriptive coding and analytical coding processes.

Descriptive coding. To categorize a school leader's framing of the problem of improving mathematics instruction, I primarily coded the interview question that asked school leaders about challenges they faced when improving mathematics instruction. I also coded problems that school leaders mentioned in other interview questions. For example, when discussing the organization of teaching, one school leader stated that they "… added a skills-based math class (*prognostic frame*) for students who were several grade levels behind (*diagnostic frame*)." To consistently code problem statements, I rearranged principals' responses to see if they could be restated as a problem. Thus, the prior school leader's statement could be rewritten as such: "A major challenge in math is that many of our students are several grade levels behind."

I also coded school leaders responses to the focal principal interview questions to understand the strategies that they implemented to improve student learning. These data primarily came from the questions that focus on the organization of math teaching and strategies for supporting teachers. Similar to coding problems identified by school leaders, I also coded school-based strategies in other interview questions. In some cases, respondents gave vague descriptions of their strategies (e.g. brokered PD to increase rigor in lessons). In such cases, I searched through the principal interview summary forms (ISFs), teacher ISFs, and school summary forms (SSFs) to find more information about the nature of learning opportunities for teachers. I added additional coding notes for such cases to keep track of coding decisions and to understand how strategies related to inquiry-oriented mathematics instruction.

For each school, I made memos (Charmaz, 2000, p. 517) for both Year 3 and Year 4 to ensure accurate data recording, to provide central access to important data, to record important coding decisions, and to record coding issues I encountered with the data. Top-level categories for school-year memos were diagnostic frames, school leaders' strategies by instructional leadership function, notes on the school and district context, methodological notes about the data, and analytical notes explaining key coding decisions. These memos were used to select cases for RQ2 because these memos had important notes about the school and district context and principal instructional leadership. For example, if a school was reconstituted at the beginning of the school year, then this would be an important contextual factor that I considered when addressing research question 2. See Appendix C for an example School-Year memo.

Analytical Coding. For analytical coding, I regrouped a subset of the descriptive codes for both problems and strategies. For problems, I recoded descriptive codes for problems into two categories: problems relating to increasing student performance, and problems relating to mathematics instruction. These two problem categories were the most prominent out of those mentioned by school leaders. I formed three subcategories under each problem based on the kind of problem and its relation to inquiry mathematics instruction: problems relating to instructional management, problems relating to general instruction, and problems relating to instructional improvement. Various problems were not considered for analytical coding because either it was beyond the scope of my research question or was an issue that was beyond the influence of the principal. For example, I did not include problems relating to the volume of content within the curriculum because this was ultimately beyond the control of the principal. This is an important problem that principals and teachers encounter, but these kinds of problems are embedded within the district and state contexts and are not issues that principals can directly influence. Additionally, it was common for school leaders not to have effective strategies to address such problems.

For strategies, I recoded descriptive codes into categories based on key instructional leadership functions: Brokering Learning Opportunities, Fostering Teacher Collaboration, and Monitoring Instruction and Student Learning. I formed three subcategories related to Brokering Learning Opportunities based on who was providing the support for teachers: Coaching, School PD, and External Consultant or External PD. I formed distinct categories because of the nature of the support and whether or not teachers could have ongoing interactions with the provider. For example, teachers could seek out coaches repeatedly throughout the school year, whereas they might only interact once with or have limited ongoing interactions with an external consultant. School-based professional development could be a one-off session, could provide the basis for organizational routines and activities that are used during collaboration, or could be part of a coherent set of professional development sessions. The instructional leadership function

Fostering Teacher Collaboration had only one top-level category. I formed two categories for Monitoring Instruction and Student Learning based on whether the strategies related to teachers' instruction or student learning: Monitoring and Supporting Student Learning, and Monitoring and Supporting Instruction.

Then, I formed three subcategories for each of the instructional leadership functions to categorize strategies in relation to the potential for improving inquiry-oriented math instruction: instructional management, general instruction, and instructional improvement (See Figure 2). Instructional management strategies typically dealt with regrouping students, rearranging teacher assignments, and reorganizing the schedule based on analysis of student achievement data. General instruction strategies were strategies that had the potential to support teachers in any content area and were not specific to ambitious instruction. Instructional improvement strategies are strategies that could potentially support math teachers in developing instruction that aims for ambitious student learning goals. Such strategies could have incorporated opportunities for pedagogies of investigation or enactment of key instructional practices, opportunities to analyze student work and reflect on how instruction influenced student learning, opportunities to solve math problems together with student thinking in mind, opportunities to understand the nature of rigorous tasks in inquiry math, or opportunities to understand rich discourse. I drew on professional development research to identify potential instructional improvement strategies. I coded strategies under instructional improvement only when there was evidence that these strategies aligned with key aspects of inquiry-oriented mathematics instruction and characteristics of effective professional development.

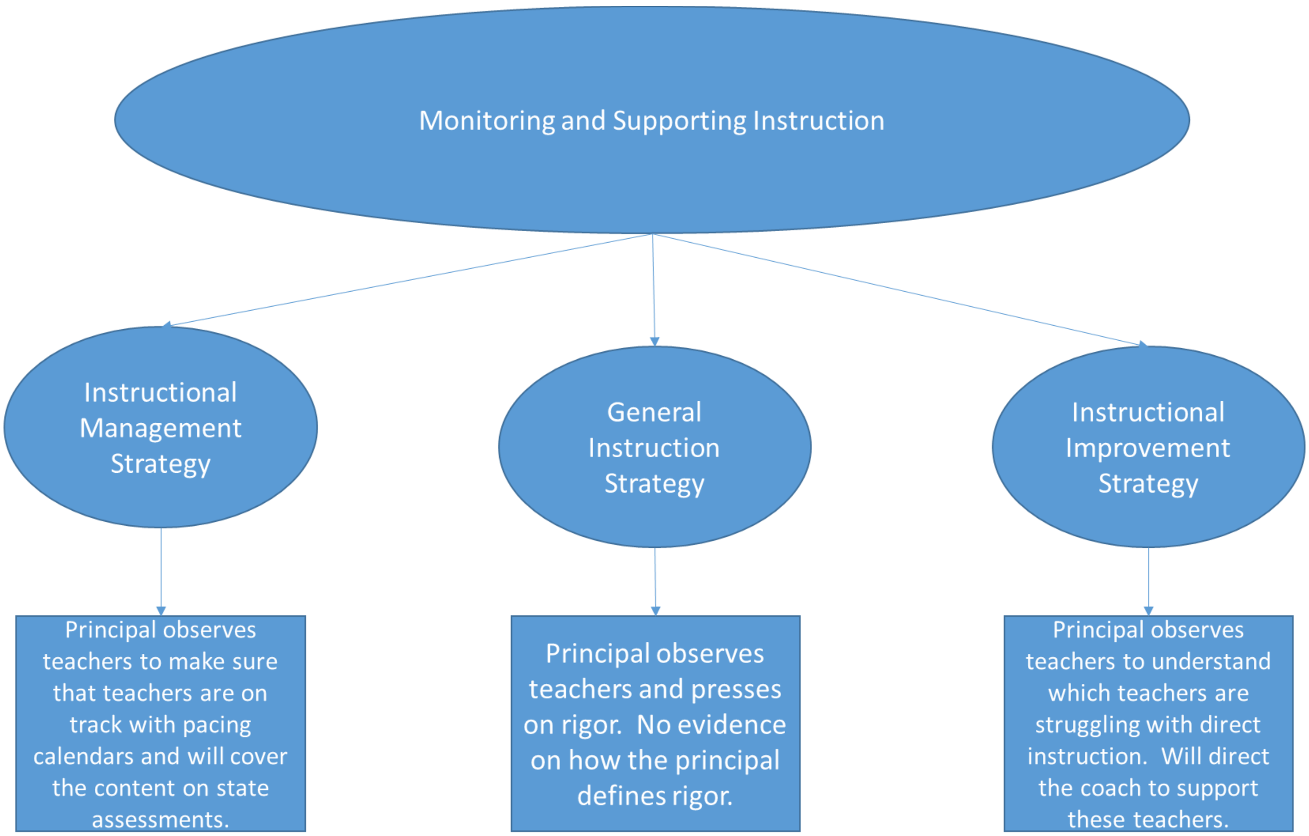
Coding Corpus of Data. I used constant comparative methods and worked with two additional coders to increase coding reliability (Strauss & Corbin, 1990). I started the descriptive coding process by randomly selecting ten school leader interviews. After coding this first set of ten interviews, I then recoded all of the descriptive codes to ensure that code definitions were consistently applied. I repeated this process for the first forty interviews. If new codes were identified, I then recoded previously coded transcripts to ensure that I consistently used code definitions. I coded the remaining thirty-one transcripts with a fairly stable codebook. I subsequently recoded all of the principal interviews to ensure that coding decisions were consistent.

To further ensure reliability, I worked with two additional coders to reach consensus on transcripts. Twenty-eight of the seventy-one transcripts were double coded. I met with each coder for training on protocols and codebooks. For training, we coded five transcripts together to help familiarize coders with the codebook and process. After training, coders were randomly assigned sets of transcripts, which varied from one to five transcripts at a time. We held meetings when each coder completed their coding assignment. Coding discussions were used to reach consensus on all descriptive codes. We held discussions if there were any coding discrepancies to come to a consensus.

Statistical analyses. To address research question one, I conducted several descriptive statistical analyses as well as logistic regression analyses to assess if there was evidence of a relationship between school leader understanding of inquiry-math (i.e. functional or form VHQMI) and their strategies for improving student learning. I first described findings for each Instructional Leadership Function. Then, I analyzed the problems that principals identified related to instruction and student learning. Third, I investigated whether there was a relationship between principals identifying problems that related to the quality of mathematics instruction and implementing instructional improvement strategies. Finally, I analyzed relationships between variables to assess if there were relationships that would confound the regression analysis.

Figure 2

Analytical Coding Structure by Function and Strategy



I then ran four logistic regression models with the implementation of any instructional improvement strategies as the outcome. Principals were coded as a "1" if they implemented any instructional improvement strategy and "0" if they did not discuss instructional improvement strategies. Standard errors were clustered within principal because some principals had two observations. Overall, there were 55 unique principals in these models and 71 observations total. The logistic regression coefficients are reported as odds ratios. If a coefficient has a value greater than 1, this indicates that, on average, the outcome is more likely to occur as the independent variable of interest increases. For example, if a logistic regression resulted in a coefficient of 3.00 for Function VHQMI, this would indicate that principals with a functional VHQMI were on average three times more likely to implement improvement strategies than principals who had a Form VHQMI. In this analysis, I controlled for district membership, years of experience as a principal in the school, and a binary variable for experience teaching mathematics. I also used various statistical tests to assess model fit and accuracy of post-estimation results.

Case Selection

To address the second research question, I used maximum variation case-selection for VHQMI and improvement strategies to understand how aspects of the district and school and district context influenced instructional leadership. I formed four groups of principals based on Form or Function VHQMI and implementation of instructional improvement or management strategies: Function-Improvement, Form-Improvement, Function-Management, and Form-Management. I used Function VHQMI as a dimension given that prior research found that principals with a functional understanding of math instruction are more likely to identify key problems in inquiry-oriented math instruction as well as implement instructional improvement strategies (Nelson & Sassi 2005). I used improvement strategies or purely management strategies as a dimension because these were the two modal configurations of strategies employed by the majority of principals in this sample.

In my dissertation, I used a different set of case selection criteria than I initially formed for my dissertation proposal. The case-selection criteria for my proposal were the presence of a coach, principals who regularly attended teacher collaboration, and principals with above average school-level ratings on the Principal Instructional Leadership Factor. I changed the case selection criteria for two main reasons. First, differences in district policies and organizations could exclude certain schools for consideration. For example, Districts B and D had instructional coaches in each school, whereas this was not the case in District A and C. Thus, by retaining this inclusion criterion, I would bias selection towards Districts B and D. Second, I proposed to construct measures of teachers' perceptions of their principal's expectations for inquiry mathematics through factor analysis. I decided to drop these criteria because, surprisingly, I found no correlation between principals' expectations for inquiry math instruction and principals implementing instructional improvement strategies. Upon further analysis, I found that there was considerable variance within this measure at the school level; some teachers reported strong principal expectations and others reported weak principal expectations. Thus, I was unclear what this survey factor was measuring due to significant variation within a school.

To guide my case selection process, I used four case selection criteria that centered on identifying school leaders who implemented coherent strategies. Research has found that it is important for instructional leaders to both establish shared goals for improvement as well as align supports with those goals (Graczewski et al. 2009). I used two aspects of instructional leadership as evidence of coherency: aligning problems with appropriate strategies (first case selection criterion), and implementing aligned strategies across multiple instructional leadership functions (second case selection criterion).

For the first case selection criterion, I considered aligned problems and strategies as evidence that school leaders were addressing key challenges that they had identified. There were cases of principals identifying problems that were central to inquiry math instruction, but not implementing strategies that had the potential to support instructional improvement. For example, a principal could report that teachers routinely reduced the cognitive demand of math tasks, but then did not implement strategies that had the potential to support instructional improvement. However, another principal could also identify that math teachers often reduced the cognitive demand of math tasks and then broker school PD that addressed maintaining the cognitive demand during lessons. The same logic held for principals who identified problems relating to instructional management and who implemented corresponding instructional management strategies.

For the second case selection criterion, I screened for principals who implemented aligned strategies across multiple instructional leadership functions. I conjectured that principals were more likely to support substantial teacher learning when they coordinated strategies across multiple instructional leadership functions. That is, school leaders who coordinated the work of coaches, district specialists, and school PD were more likely to provide conditions in their schools that could support teacher learning. To build on the previous example, a principal might press on teachers through observation and feedback to maintain the cognitive demand of tasks during investigations. In this example, the principal would be using strategies from two different instructional leadership functions to support teacher learning around the same instructional issue of maintaining the cognitive demand: Brokering Learning Opportunities – School PD, and Monitoring and Supporting Instruction.

The third selection criterion concerned the degree to which principals implemented either instructional improvement or management strategies. This criterion was used to differentiate between principals who had strategies that spanned the same number of instructional leadership functions. For example, if two principals both implemented improvement strategies in both the School PD function and Monitoring and the Supporting Instruction function, then I counted the total number of aligned strategies implemented to decide which principals to include. For example, under the Monitoring and Supporting Student Learning Function, principals could track students into different classes based on student performance, have an additional skills-based class for students who did not pass the state test, target students for tutoring based on performance, and encourage the use of adaptive computer software. I counted this set as four different instructional management strategies. I then summed the strategies across all instructional leadership functions and took the total number of strategies as a potential indication of how prevalent instructional improvement strategies were within the school. This third case selection criterion served a "weeding out" function. The main reason why I used this as the third case selection criteria is that school leaders could list multiple strategies within a particular instructional leadership function, but not necessarily have strategies that span different instructional leadership functions.

For some groups of principals, I used district membership as a fourth criterion for selecting cases. I primarily used this criterion to avoid selecting all four school leaders from the same district, which was the case for both the Function-Improvement group and the Form-Improvement group. By varying district membership, I further assessed how differences in district context shaped principal instructional leadership while also identifying common aspects of effective instructional leadership that spanned multiple districts.

Data for Research Question 2

Do aspects of the school and district context influence whether a school leaders' understanding of inquiry-oriented math instruction informs the kinds of strategies they implement?

After selecting the sixteen case-study schools, I then constructed a database using various sources from the MIST project. Data described key aspects of the school and district context, instructional expertise within the building, assessment and accountability pressures, instructional leaders within the school, and student demographics. I also used several research tools from the MIST project: principal interviews, principal ISFs, teacher interviews, School Summary Forms (SSFs), measures of expertise, student demographics, and student performance on state tests. In the following sections, I describe these sources of data.

Principal Interview Transcripts and Principal Interview Summary Forms. I used both the principal interview and the principal ISFs to understand and code principals' problem statements and strategies as they pertained to improving the quality of mathematics instruction. In contrast to the analysis for RQ1, I coded the entire principal interview transcript. By reviewing these data, I identified additional aspects of the district context, such as accountability pressures, district leader expectations, and additional aspects of the school and district context that might influence the nature of principal instructional leadership (e.g. additional discretionary funds from the state because of low student performance). If both the principal and assistant principal oversaw the math department, then I reviewed and coded the interviews and ISFs for both school leaders. Similar to my analysis for RQ1, I used the principal ISFs to ensure that I was not over-interpreting the data and to ensure that I had not missed key aspects of the school and district context from the principal interview.

School Summary Forms. I used the School Summary Forms (SSFs) to collect additional information about the school and district context and to more fully understand how improvement or management strategies were implemented in schools. The SSF was compiled by several MIST team members in the spring of each study year. An SSF contains information and analyses on how district policies were implemented in each school. An SSF synthesized data from teacher interviews, coach interviews, and school leader interviews. I used the SSFs to understand which math courses were offered, which curricula were used, frequency and type of meetings for math teachers, supports for currently struggling students, professional development for math teachers, nature of student tracking if present, and potentially important aspects of the school and district context that might not have been addressed in interview protocols. Furthermore, I used the SSFs to triangulate reports from teachers, coaches, and school leaders to verify which strategies were implemented in the school. This triangulation helped me determine if teachers and school leaders reported similar learning events or supports for teachers. I also used the triangulation process to highlight key differences between teachers' reports and school leaders' reports. In some cases, principals reported professional development that had the potential to support teacher learning; however, math teachers in the MIST sample did not report attending such professional development. In one example, a principal noted that teachers would routinely lower the cognitive demand by instructing students on algorithms and "proceduralizing" complex tasks. The principal reported that the coach led a PD session on how to maintain the cognitive demand, but neither the teachers' reports nor the coach's reports confirmed the occurrence of PD on maintaining the cognitive demand. In this case, I did not code the PD as an instructional improvement strategy.

Measures of Expertise. I used the Instructional Quality Assessment (IQA) (Matsumura et al. 2008), MKT (Hill et al. 2004), and VHQMI scores (Munter 2014) for teachers and coaches to assess the likelihood of instructional expertise being present within a school. It is important to note here that the MIST team collected data typically for up to five math teachers in a school; however, most middle schools had more than five mainstream middle school math teachers. To reduce selection bias, MIST researchers used randomization to select potential research participants. MIST also "snowballed" teachers, coaches, or administrators who were important instructional leaders but not included initially in the sample. The MIST researchers decided to snowball participants either in the field or within a couple of weeks after January data collection.

To determine if there was instructional expertise within the MIST sample, I used two measures for IQA: IQA bands and mean IQA score. Each spring, all teachers and coaches who also have teaching assignments have one class period recorded on consecutive days. Members from MIST then coded these videos using the IQA rubrics in the summer at the conclusion of the school year. I considered only the lesson with the highest IQA mean score. In some cases, one lesson spanned both days of video recording. The IQA Band measurement has four ordinal lesson categories: Traditional, Proceduralized, Needs Help with Discussion, and Ambitious (see Appendix D for a description of these categories). This measurement was developed in a previous analysis (Rigby et al. 2017) and synthesizes research conducted by math educators as well as MIST findings (Franke et al. 2007; Stein et al. 1996; Wilhelm 2014; Stein et al. 2008)). For this measurement, I considered that there was evidence of expertise in the school if a teacher's lesson was categorized as NHWD or Ambitious. In Ambitious lessons, teachers selected cognitively-demanding tasks, maintained the demand throughout a lesson, and orchestrated a whole-class discussion that pressed students' on justifying their mathematical solutions. In NHWD lessons, teachers were able to select and enact cognitively-demanding tasks, but they were unable to facilitate productive whole-class discussions, possibly due to insufficient time. Importantly, few math teachers in the MIST study had the capacity to orchestrate high-quality whole-class discussions (Wilhelm 2014), which could influence students' enduring understandings of key content (Lampert, 1990).

For evidence of extensive pedagogical content knowledge, I used some of the dimensions from the MKT (Hill et al. 2004). The MKT is a multiple-choice assessment that all full-participant math teachers and coaches took each Spring. The assessment I used for this analysis focuses on how well middle school teachers understand middle grades content and how well they understand different representations of equivalent solutions (add Hill citation). The MIST team collected measurements in two domains of knowledge: Numbers, Computation, and Operations (NCOP); and Patters, Functions, and Algebra (PFA). Scores for each dimension were normed on a nationally representative sample of teachers and reported in standard deviation units. I took the mean of the two MKT dimensions to construct a composite score. The sample mean for MIST participants is equivalent to the nationally representative mean for middle school math teachers. If teachers or coaches were one standard deviation above the mean, then I took this as evidence that these participants had a deeper understanding of middle school mathematics and were potential sources of expertise for their fellow teachers. Such expertise and understanding of mathematics instruction can be helpful when planning for future instruction. Similarly, if teachers or coaches were one standard deviation below the mean, then I took this as evidence of weak pedagogical content knowledge. If a significant number of teachers in a school have weak pedagogical content knowledge, then this could potentially limit planning conversations, which in turn could affect task selection and enactment. It is important to keep in mind that a complex relationship exists between MKT and IQA. Teachers with a high MKT might not have developed sophisticated instructional practices, which would result in low IQA scores.

For VHQMI, I used individual dimensions as well as the Form/Function distinction. If teachers and coaches had a functional understanding of inquiry math, then I conjectured that they were more likely to plan lessons that aligned with inquiry math. Also, if teachers or coaches had a functional understanding of VHQMI, then I took this as a potential indicator of capacity to support other teachers during lesson planning activities during TCT. Similar to MKT, participants' VHQMI is not indicative of their inquiry-oriented mathematics instruction.

Out of these three measurements, I used the IQA measurements to be the strongest indication of instructional expertise given that there is direct evidence that teachers can enact lessons that align with inquiry-oriented mathematics instruction. Correlations for this sample for each of these measures were relatively low (less than 0.30).

Student Performance. To understand student performance, I used data on the percentage of students proficient by grade level, NCLB Stage, and whether or not schools met AYP targets overall and for math specifically. Although some schools data for NCLB Stage and AYP status were missing, there were data for the percentage of students proficient for all schools. I compared school proficiency rates by grade level to district proficiency rates to form an understanding about how each school performed relative to the district average and thus conjectured whether or not district leaders used this relative performance to press on student performance differentially school-by-school. These data were also triangulated with principal and teacher reports of accountability expectations to understand how student performance on state tests influenced instructional leadership within the school. When available, I used NCLB Stage data and AYP status to understand how the school had performed on previous state assessments. For example, if a school was at Stage 5 under NCLB, then it was likely that the school had not met AYP targets for at least six consecutive years. There were also different sanctions for schools based on AYP Stage, with some schools under threat of reconstitution if they remained at the lowest stage, Stage 5, for multiple school years. NCLB sanctions at each stage varied by state.

Student Demographics. I used MIST databases to obtain data on student demographics of interest: racial demographics of students, the percentage of English Learners (ELs), and the percentage of students receiving free and reduced prince lunches (FRL). I used these data to investigate whether and how student demographics shaped instructional leadership. For example, schools with a large EL population would need more bilingual teachers and resources to support ELs than schools with a small EL population. Also, math teachers in schools with a large EL population would need to be supported in teaching language learning in addition to mathematics. Thus, school leaders in schools with large EL populations might have limited resources and time for professional development that directly aligned with important aspects of inquiry-math instruction. Furthermore, schools with a high percentage of students receiving FRLs might have to use additional resources for student support services. It is important to note that the majority of the schools in the MIST study had a high percentage of students who received FRL. Similar to student performance statistics, I compared school demographics with district averages to form initial conjectures about the relative needs of students in that school and how these needs could influence principal instructional leadership. These conjectures were further assessed when analyzing the principal interview, principal ISFs, and SSFs.

Analysis for Research Question Two

To address my second research question, I did a comparative case analysis of four different groups of principals to understand how aspects of the school and district context shaped principal instructional leadership. The four groups of principals were formed based on understanding of inquiry-oriented mathematics instruction (Function VHQMI/Form VHQMI) and principals' strategies for improving student learning (instructional improvement/instructional management).

I selected four principals for each group to identify common patterns and differences within each group. Multiple cases within each group also helped me identify consistent patterns and differences in instructional leadership within each group.

To investigate RQ 2, I first generated memos for each school that summarized key aspects of the school and district context that could influence instructional leadership. Memos included categories for school leader's professional background, distinguishing aspects of the school context (e.g. school received a federally-funded School Improvement Grant), student demographics, student performance on high-stakes state assessments, school leader reports of district leaders' expectations, school leader professional development that focused on inquiry-oriented math instruction, evidence of teachers' instructional expertise, identifying and leveraging expertise for supporting teacher learning, key problem statements and strategies for improving student learning, and methodological concerns. See Appendix E for a brief example of a School Context memo. To generate each memo, I used student achievement data, student demographics, read through all school leader interviews from that study year, read through ISFs and SSFs, and collected data on measures of expertise. Throughout this process, I made analytical notes about aspects of the school or district context that could have influenced school leaders' problem statements and strategies for improving student learning. For example, one low-achieving school participated in a pilot program that rewarded teachers with substantial bonuses if the school met student performance targets. Recording these analytical notes helped me understand how aspects of the district and school context influenced instructional leadership.

I used a set of conjectures to analyze each School Context memo to understand how aspects of the school and district context shaped instructional leadership. These conjectures were formed based on prior research, fieldwork experience in MIST, and analysis of RQ 1. Appendix F lists the main conjectures by category: Organization of Teaching, District Leader Expectations, Accountability Pressures, Experience and Expertise of Teachers and Coaches, principals' advice-seeking interactions, and Student Demographics. Conjectures were refined throughout the analysis. If I formed new conjectures based or revised conjectures throughout the analysis, then I used constant-comparative methods to re-analyze relevant data. The constant comparative method ensured that I analyzed each included school and year with the same conjectures.

After generating a memo for each of the sixteen case-study schools, I then made a Quadrant Memo for each group of principals to understand key similarities and differences between instructional leadership for principals in the same group. See Appendix G for a brief example of a Quadrant memo. I first summarized key findings for each school within a quadrant for several categories: professional background, school and district context, student demographics, student performance, accountability pressure as reported by school leaders, professional development for school leaders, identifying and leveraging expertise for supporting teacher learning, teachers' instructional expertise, problems and strategies for supporting student and teacher learning, perspectives on how improvement occurs, and summary of key findings. Many of the categories for the quadrant memo overlapped with categories in the School Context memo. For the overlapping categories, I further summarized information to highlight the most salient aspects of the school and district context that could influence instructional leadership within the school. I added two new categories to the Quadrant memo: Perspectives on Improvement and Summary of Key Factors. These categories summarized key learning events available for teachers, key school leadership professional development events, and important school and district factors that shaped principal instructional leadership.

After I compiled each Quadrant memo, I then used conjectures for each of the categories in the memo to identify patterns in instructional leadership. For example, if all four principals within a group didn't have access to instructional expertise, then I made low-level inferences on how this influenced instructional leadership. To assess the reasonableness and validity of these inferences, I cross-referenced each inference with other data in the school or with findings from prior research. For example, if principals had not attended PD that supported their understanding of inquiry-oriented math instruction, then I inferred that it was unlikely for principals to identify problems related to inquiry-math instruction because they didn't have opportunities to develop an understanding of effective instruction through PD. Prior research has found that most principals require support in understanding aspects of effective inquiry-oriented math instruction before implementing strategies that have the potential to support teacher learning (Nelson & Sassi 2005). Thus, I would conclude that lack of relevant learning events likely limited the development of instructional improvement strategies. I went through each category in the Quadrant memo to identify common patterns and differences. I then recorded these analytical notes for further comparison with other groups of principals.

After summarizing findings by Quadrant, I then analyzed principals with similar strategies (e.g. all eight principals who implemented improvement strategies) to see if there was evidence that understanding of math instruction related to principal instructional leadership. For example, if six of the eight school leaders who implemented improvement strategies brokered learning events for math teachers through district math specialists, then I inferred that turning to relevant expertise was not dependent upon having a functional understanding of inquiry-oriented math instruction. I did this for both sets of principals (e.g. principals who implemented improvement strategies and principals who implemented management strategies) and for all categories in the Quadrant Memo.

The final analysis for my second research question involved drawing comparisons between principals with improvement and management strategies to understand further if there were consistent aspects of the school and district context that influenced the types of strategies principals implemented. For example, it could turn out that principals who implemented improvement strategies also consistently worked with teachers who had instructional expertise. Thus, access to instructional expertise might influence the nature of principal instructional leadership, which then has implications for principals' roles in districts that aim for ambitious instructional practices. I conducted this analysis for all of the categories in the Quadrant memo to understand if there were common patterns between aspects of school and the district context and principal instructional leadership.

Limitations

This study was constrained by its reliance on previously collected MIST data. This limitation is important to acknowledge because I did not have opportunities to modify interview protocols for future data collection or conduct follow-up interviews with principals after encountering data that were unclear. One common issue was that protocols did not request interviewers to probe on how strategies connected to teacher learning or how strategies related to issues that the school leader had identified with current math instruction. In some cases, interviewers probed on the "why" of strategies or principals explained their justification without further probing. There were several cases though in which it was hard to discern if principals were addressing problems of student learning or current instruction through the implementation of relevant strategies. This is important given that prior studies have found that effective instructional leadership is founded on coherent strategies focused on improving student learning (Bryk et al. 2010). In future investigations, it will be important to design interview protocols that press school leaders to describe how strategies relate to goals for teacher learning to further understand the coherency of instructional leadership.

Another limitation of this analysis was that I triangulated data from interviews to understand what kinds of learning events occurred in schools. The grain size and type of data made it challenging to understand opportunities for teacher learning in these events, particularly as they related to supporting teachers' development of ambitious instructional practices. Broadly, I was able to discern the focus of learning events, such as the top-level content of a PD session. However, I was not able to identify what activities teachers participated in, and how facilitators pressed on teachers' pedagogical reasoning. To ensure strict coding of learning events that had the potential for instructional improvement, I analyzed data to check that teachers and other school members had similar reports of learning events and that learning events were led by educators with expertise or had successful reputations (e.g. CMP2 PD in Michigan). When possible, I relied on measures of expertise and MIST institutional knowledge to draw inferences about the likelihood that facilitators could support substantial teacher learning.

CHAPTER 4

FINDINGS

In this chapter, I report on findings for my two central research questions:

1. Does a relationship exist between school leaders' depth of understanding of mathematics instruction (i.e. VHQMI) and their orientations for improving student learning?

2. Do aspects of the school and district context influence whether a school leaders' understanding of inquiry-oriented math instruction informs the kinds of strategies they implement?

The main two sections of this chapter focus on each question in turn. In the subsequent chapter, I synthesize findings, discuss implications for principal practice and instructional leadership, and discuss future directions for research.

Findings and Analysis for Research Question 1

In this section, I report my findings on relationships between principals' Function VHQMI and implementation of improvement strategies, while controlling for district membership and principal experience. To address my first research question, I coded 71 school leader interviews from Year 3 and Year 4 of the study. I first discuss the strategies principals implemented, which are organized by instructional leadership function. I defined the instructional leadership functions of interest in Chapter 2: Brokering Learning Opportunities – Coaching: Brokering Learning Opportunities – External Training, Brokering Learning Opportunities – School PD, Fostering Teacher Collaboration, Monitoring and Supporting Instruction, and Monitoring and

Supporting Student Learning. I then discuss results for the two different categories of school leaders' problem statements: Problems Related to Current Instruction, and Problems Related to Student Learning. After reporting school leaders' problem statements and strategies, I describe and summarize relationships between variables for the logistic regression models. Last, I report a series of logistic regression models in which the outcome of interest is the implementation of any instructional improvement strategies.

School Leaders' Strategies by Instructional Leadership Function

Brokering Learning Opportunities: Coaching. Overall, school leaders did not describe the work of the math coach in ways that could support instructional improvement at scale. Twenty-three school leaders discussed strategies related to math coaching in their school with nineteen of those leaders mentioning strategies that had the potential to support teachers in any content area (See Table 5). For this table and for the tables to follow, a school leader could be coded for each of the different top-level strategies (e.g. coded for implementing management strategies, general instruction strategies, and improvement strategies). Thus, adding the number of school leaders at each top-level strategy could result in a sum that is greater than the total number of principals coded for that specific instructional leadership function. For example, twenty-three school leaders described instructional leadership strategies that related to school-based math coaches. Some principals were coded for multiple top-level strategies, given that ten school leaders implemented management strategies, nineteen school leaders implemented general instruction strategies, and five school leaders implemented improvement strategies. The sum of principals at the top-level, thirty-four, which is greater than the total number of school leaders because some principals were coded into multiple top-level strategies.

Eight school leaders who described the role of the coach did not elaborate the work of the coach in any detail, which suggests that these principals did not leverage coaches as supports for teacher learning. Prior research has found that school leaders' understanding of the role of the coach and elaboration of this role can relate to both how the principal positions the coach as a source of expertise and of the extent to which teachers access the coach (Matsumura et al. 2009). If principals did not elaborate on the role of the coach, then it likely indicates that they did not position the coach as a source of expertise for her teachers.

Ten school leaders' strategies were coded as directing the coaches to implement instructional management strategies. Six school leaders described the importance of coaches preparing student achievement data reports to share with the staff. Additionally, six school leaders described how coaches pulled out low-performing groups of students for tutoring or taught an additional class that targeted low-performing students. Overall, these strategies aimed at improving student achievement through developing students' basic skills. Crucially, these instructional management strategies did not make connections between the nature of prior mathematics instruction, evidence of student learning, and how the coach could function as a support for substantial teacher learning.

Five school leaders discussed directing the work of the coach in ways that could support math teachers in developing inquiry-oriented mathematics instruction. Four of these school leaders described coaching cycles that focused on aspects of inquiry-oriented instruction, such as planning and enacting lessons with sufficient depth. Interestingly, four of the five school leaders who implemented improvement strategies for coaching were in District D. In general, math coaches in District D had more instructional expertise than the math teachers in the other three districts. Teachers and coaches in District B had similar levels of expertise, which could explain why school leaders in District B were less likely to leverage coach expertise. Math coaches in both District A and District C had higher MKT scores than their respective teachers while having similar VHQMI scores. However, fewer schools in both District A and District C had an assigned math coach because math coaching was not a central plank of the instructional improvement effort in either district. This likely explains why principals were less likely to leverage coach expertise in District A and District C.

Table 5

Brokering Learning Opportunities: Coaching

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	10*
Data Analysis	6
Teach or Tutor Struggling Students	6
General Instruction	19
Support Teachers –Vague	8
Support New or Struggling Teachers	4
Co-Plan	3
Plan and Lead PD	3
Co-teach	2
Observe and Give Feedback	2
Plan PD with SLs	1
Substitute Teach	1
Instructional Improvement	5
Coaching-Cycle Inquiry Math	4
Press on Direct Instruction	1
Total Unique School Leaders	23

*Each count represents the unique number of school leaders coded in each category.
Note: Each school leader could implement multiple top-level strategies (e.g. instructional management, general instruction, instructional improvement). The sum from these top-level strategies could be greater than the sum of total unique school leaders.

Brokering Learning Opportunities: School PD. Approximately 15% of the school leaders described how they brokered school-level professional development opportunities for math teachers. Five school leaders described school development sessions that focused on either developing important inquiry-oriented instructional practices or leveraging student discourse to improve student learning opportunities. Four school leaders described professional development sessions that could support teachers in any content area or provided insufficient descriptions on the depth of activities (e.g. professional development on rigor). The remaining two school leaders discussed implementing strategies that related to instructional management, such as brokering PD opportunities in which teachers analyzed student performance data and planned lessons to reteach. Overall, only five principals brokered learning opportunities through school professional development that were consistent with the district's vision for improving mathematics instruction. Linking school professional development to broader district supports has been found to increase the likelihood of instructional improvement at the scale of a school district (Graczewski et al.2011).

Table 6: Brokering Learning Opportunities: School PD

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	2
Analyzing Performance Data	1
Training on Assessing Gaps in Basic Skills	1
General Instruction	4
Language Development	2
Increase Rigor	2
Culturally Responsive Pedagogy	1
Instructional Improvement	5
LES Instruction	3
PD on Leveraging Discourse in Inquiry Math	2
Total Unique School Leaders	11

Brokering Learning Opportunities: Supports External to District. Overall, only five school leaders implemented strategies that involved either external consultants or external PD. Interestingly, three of the five school leaders implemented strategies that had the potential to support instructional improvement. Two of these school leaders, both in District D, sent their math teachers to the CMP2 PD in Michigan, a week-long summer professional development workshop designed by math educators. In this PD, teachers have opportunities to solve math tasks with student thinking in mind and plan upcoming instruction under the guidance of facilitators with expertise. A third principal discussed brokering a PD session in which an external consultant led a PD session that focused on planning CMP2 investigations while considering common student misconceptions. The principal reported that the facilitator in these sessions pressed teachers to consider how to maintain the cognitive demand of tasks throughout the lesson. The remaining two principals discussed brokering opportunities for PD that related to either instructional management or general aspects of instruction (e.g. data analysis, laying out what is to be taught in the upcoming weeks -calendaring, and rigor).

Table 7

Brokering Learning Opportunities: External Training

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	1
Data Analysis for Reteaching	1
General Instruction	1
PD on Calendering	1
PD on Rigor	1
Instructional Improvement	3
CMP2 Michigan State PD	2
PD on Planning Investigations	1
Total Unique School Leaders	5

Strategies for Teacher Collaborative Time. Twenty-seven school leaders discussed teacher collaboration, but only five elaborated on it related to instructional improvement (e.g. planning investigations based on student thinking, analyzing student work to understand student thinking, and solving math tasks together). The majority of principals discussed either content general strategies or instructional management strategies (See Table 8 below). Twenty school leaders discussed strategies that could apply to instruction in any content area, such as laying out the instructional calendar for the next instructional unit (10 school leaders) or sharing instructional resources (10 school leaders). Common throughout these descriptions of strategies was a lack of detail or elaboration on how such strategies could support instructional improvement or student learning. That is, sharing resources can help teachers have more ways to teach content, but such sharing does not necessarily change the nature of student learning opportunities. Very few principals elaborated on how TCT could be leveraged to understand the nature of mathematics instruction, how it could shape students' conceptual learning, and how evidence of student thinking could be analyzed to plan future instruction. Seventeen principals discussed the importance of using TCT to implement instructional management strategies. The most prevalent strategy typically included analysis of student achievement data to categorize students and assess which students needed additional instruction on basic skills. Additionally, this strategy primarily focused on providing additional resources for students who were close to proficient. Few principals described teacher collaboration as a key strategy in which teachers had opportunities to analyze student learning and plan future instruction that focused on conceptual development.

Table 8

Strategies for Teacher Collaborative Time

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	17
Analyze Student Performance Data	16
Using Common Assessments to Reteach	3
General Instruction	20
Calendering	10
Share Resources and Strategies	10
Design Common Assessments	3
Planning – Vague	3
Analyze Student work-general	2
Discuss lesson plans	2
Model Instruction	2
Observe Other Teachers	1
De-brief on lessons	1
Plan Vocabulary Instruction	1
Instructional Improvement	5
Planning mathematical investigations based on student thinking	3
Analyzing student work to understand student thinking	2
Use TCT to solve math tasks together	1
Total Unique School Leaders	27

Strategies for Monitoring and Supporting Current Instruction. Thirteen of the twenty-four school leaders who discussed monitoring and supporting current instruction discussed strategies that had the potential to support instructional improvement. Common strategies included pressing teachers on direct instruction and principals asking students conceptual questions during investigations. School leaders in District A and District D were more likely than those in District B and District C to discuss strategies that could press teachers on current math instruction. Interestingly, three school leaders discussed supporting teacher learning directly through conducting coaching cycles with teachers (3 school leaders). It was surprising to find principals conducting coaching cycles given both the time needed (i.e. planning the lesson, observing the lesson, and giving feedback after the lesson) and expertise required for the strategy to be effective.

Table 9

Summary of Strategies for Monitoring and Supporting Current Instruction

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	6
Press Teachers to Reteach low standards	3
Press Ts to Keep up with Pacing Guides to Optimize test scores	2
Bell-to-bell instruction	1
General Instruction	10
Content-General Feedback	4
Press Ts to Keep up with Pacing Guides to Cover Content	2
Assess if students are engaged	1
Press on Teachers to Implement PD	1
Encourage and Support Students	1
Multiple Admins observe all teachers	1
Place teachers for next year	1
Reviews Lesson Plans	1
Identifying which teachers need to be exchanged	1
Instructional Improvement	13
Press on Teachers who use Direct Instruction Strategies	5
Assess student understanding of math concepts	4
Conduct Coaching Cycle with Teachers	3
Use math-specific observation tools to discipline vision	2
Press teachers to plan lessons with sufficient depth	1
Co-Observe with Math Coach	1
Total Unique School Leaders	24

Sixteen school leaders mentioned strategies that were categorized as either general instruction or instructional management. Ten school leaders implemented strategies that could support teachers in any content area (e.g. assessing student engagement) or were important for managing the math department (e.g. using observations to determine teacher placement). Six school leaders mentioned how they used instructional management strategies when monitoring teachers' instruction, such as pressing teachers to reteach content that had low student performance.

Strategies for Monitoring and Supporting Student Learning. Almost all school leaders (68 out of 71) mentioned strategies that focused on student learning; however, the vast majority of these strategies focused on identifying students with low performance on procedurally-oriented assessments (65 out of 68). Common strategies included placing low performing students in an additional math class that focused on basic skills, reteaching standards with low student performance, targeted tutoring, and using adaptive computer software to develop basic computational skills. Overall, the emphasis of these strategies was on improving students' basic skills rather than on understanding what students didn't learn and how this related to teachers' instruction.

Four school leaders mentioned the importance of adding a second math class that gave students opportunities to develop a conceptual understanding of mathematics. Three of these four school leaders were from District A, suggesting that there were likely aspects of the district context that shaped how principals thought about supporting student learning. Importantly, teachers in District A had greater instructional expertise on average than teachers in the remaining three districts; it is possible that principals in District A were supported in understanding how effective inquiry-oriented math instruction supports student learning.

Table 10

Summary of Strategies for Monitoring and Supporting Student Learning

Type of Strategy	**Count of Unique School Leaders**
Instructional Management	65
Track students into different classes	53
Add Additional Class -- Skill Development	46
Reteach Part or Entire Lesson	22
Target Students for Tutoring	17
Use Computer Software that assesses basic skills	13
Implement RTI	8
Structure Camps or Intervention Days	6
Form Homogenous groups within a class based on ability level	3
Use Additional Skills-Based Curricula	1
Post Math around building -- change this	1
General Instruction	11
Focus on Student Motivation	4
Form Heterogeneous Groups within a class	3
Implement Content-Wide Academic Programs	3
Implement AVID	2
Focus on Classroom Management	2
Implement Student Mentoring Programs	1
Instructional Improvement	4
Add Additional Class -- Problem-Solving Skills	2
Add Additional instruction – Conceptual	2
Total Unique School Leaders	68

Problems Related to Current Instruction and Student Learning

Problems Related Directly to Current Instruction. Almost two-thirds of the thirty-five school leaders who discussed problems relating to instruction focused on the quality of inquiry-oriented math instruction (See Table 11). Thirteen of these school leaders mentioned that teachers would often use direct instruction and teach students procedures. Relatedly, some school leaders mentioned either that math teachers struggled to plan lessons with sufficient depth (n=6) or that teachers had insufficient pedagogical content knowledge to maintain the cognitive demand of math tasks or foster productive whole-class discussions (n=4). It is important to note that not all principals who identified challenges that teachers faced when developing inquiry-oriented mathematics instruction implemented strategies that could support teacher learning. Identifying relevant problems does not mean that principals understood how to support teacher learning or had access to instructional leaders who could directly work with teachers.

Table 11

Summary of Problems Identified in Current Instruction

Type of Problem	Count of Unique School Leaders
Instructional Management	7
Teachers need support analyzing data	7
General Instruction	13
Differentiating instruction to support all students	6
Many ELL students with different needs	3
Lack of Belief that all students can learn	2
Classroom Management	2
Forming relationships with Students	1
SPED teachers teaching mainstream content	1
Instructional Improvement	23
Direct Instruction	13
Planning lessons with adequate depth	6
Insufficient Pedagogical Content Knowledge	4
Insufficient content knowledge	2
Inducting new teachers to CMP2	1
Orchestrating whole-class discussions	1
Overteaching basic skills	1
Planning lessons that have multiple entry points	1
Total Unique School Leaders	35

Interestingly, seven school leaders mentioned that teachers needed additional training on how to analyze student performance data so that they would be more effective in identifying groups of low-performing students and content that should be retaught. However, they did not describe how teachers could use performance data to understand student thinking and plan effective inquiry-oriented mathematics instruction.

Problems related to Student Learning. Forty-five school leaders described problems relating to student learning (see Table 12). Of those, twenty-eight school leaders mentioned challenges relating specifically to student performance and used student proficiency categories identify students (e.g., basic, novice, proficient, etc.). Twenty-one school leaders suggested that students lacked foundational knowledge for their math courses. In doing so, they described gaps in student learning about knowledge and skills rather than in terms of categories of performance on high-stakes assessments. I coded this problem framing under General Instruction Problems given that students could lack foundational knowledge in any content area. Only four of the thirty-five school leaders described problems of student learning that related directly to the challenges students encounter when learning key mathematical concepts, learning key mathematical representations, and developing mathematical argumentative practices (e.g. forming and testing conjectures, making generalizations, etc.). Similar to strategies for Monitoring and Supporting Student Learning, more school leaders problematized student performance in relation to basic skills rather than developing enduring understandings of mathematical concepts.

Table 12

Summary of Problems Related to Student Learning

Type of Problem	**Count of Unique School Leaders**
Instructional Management Problems	28
Students are not performing at proficient levels	25
Large Achievement Gaps for African American Students	6
General Instruction Problems	21
Students lacking foundational knowledge	21
Student Motivation	1
Instructional Improvement Problems	4
Students need assistance developing concepts and argumentation	4
Total Unique School Leaders	45

Implementation of Instructional Improvement Strategies

Overall, 29 out of 71 school leaders (41%) implemented at least one instructional improvement strategy (See Table 13). A contingency test indicated that there was no direct relationship between Function VHQMI and implementing at least one improvement strategy ($\chi^2(1) = 0.37$, $p = 0.54$).

Table 13

Implementation of Improvement Strategies by VHQMI

Presence of Improvement Strategies	**Form VHQMI**	**Function VHQMI**	**Total**
0	29	13	42
1	18	11	29
Total	47	24	71

There is some indication of a relationship between district membership and implementation of improvement strategies, but the result is not statistically significant ($\chi^2(3) = 4.90$, $p = 0.18$). About half of the school leaders in both A and D implemented instructional improvement strategies. School leaders in District B (about one in three leaders) and District C (about one in 4 leaders) were less likely to implement improvement strategies. I further discuss relationships between district membership and the implementation of improvement strategies when reporting findings of the logistic regression analyses.

Table 14

Implementation of Improvement Strategies by District

Presence of Improvement Strategies	**District A**	**District B**	**District C**	**District D**	**Total**
0	11	10	12	9	42
1	11	5	3	10	29
Total	22	15	15	19	71

Relationships between Problem Identification and Implemented Strategies

There was a statistically significant relationship between identifying problems that related to instructional improvement and implementing instructional improvement strategies (see Table 15). Of the twenty-five school leaders who identified problems relating to instructional improvement, 60% of those principals also implemented instructional improvement strategies. Similarly, if principals only identified problems relating to instructional management, then they tended to implement instructional management strategies. Nearly two-thirds of the 34 principals who only identified problems relating to instructional management implemented instructional management strategies. This relationship between problem identification and strategy implementation was statistically significant ($\chi^2(1) = 4.47$, $p <0.05$). Thus, there was a relationship between the kind of problem that a principal identified as central and their strategies to address the identified problem.

Table 15

Comparison of Problems Relating to Instructional Improvement and Improvement Strategies

	Management Strategies	**Improvement Strategies**	**Number of Principals**
Management Problems	23	11	34
Improvement Problems	10	15	25
Number of principals	27	22	59

Logistic Regression Analyses

Descriptive Statistics. For this analysis, I collected data on the type of school leader, experience teaching math, and experience as a school leader in their current school. Principals were more likely to be in charge of the math department than assistant principals, with forty-five principals considered in comparison to twenty-six principals (see Table 16). Thirty-two of the school leaders reported that they had some experience teaching mathematics, with twelve of those leaders located in District A. About forty percent of principals had 1-2 years of experience in their current schools, about forty percent had 3-4 years of experience, and about twenty-percent had more than four years of experience. There were no statistically significant differences between district membership and school leader experience in school.

Table 16

Summary of Descriptive Statistics for School Leaders by District

	Principal	**Assistant Principal**	**Taught Math**	**1-2 Years in School**	**3-4 Years in School**	**>4 years in School**
Dist. A	19	3	12	10	8	4
Dist. B	7	8	6	6	7	2
Dist. C	8	7	9	5	6	4
Dist. D	11	8	5	7	7	5
Total	45	26	32	28	28	15

Relationships between Variables. Table 17 summarizes bi-variate relationships between the outcome and predictor variables. Given that the predictors were either binary or categorical, I ran several different types of statistical tests. With regards to the implementation of improvement strategies, there were only two statistically significant bi-variate relationships: school leaders who had previous experience teaching math were less likely to implement improvement strategies, and school leaders who were in their schools for more than four years were more likely to implement improvement strategies. No other statistically significant bi-variate relationships were identified. Importantly, the Function VHQMI measure was not related to the implementation of instructional improvement strategies. Furthermore, there was no relationship between school leaders who had taught math and Function VHQMI. In the following section, I use these descriptors in a regression analysis.

Table 17

Summary of Relationships between variables

	Presence of Improvement Strategies	**Function VHQMI**	**Taught math**	**Years in School**
Presence of Improvement Strategies	1			
Function VHQMI	No relationship (χ^2 test)	1		
Taught math	Negative Relationship at 0.05 level (χ^2 test)	No Relationship (χ^2 test)	1	
Years in School	Positive relationship at 0.10 level (χ^2 test)	No Relationship (χ^2 test)	No Relationship (χ^2 test)	1

Logistic Regression Results. Table 18 below shows the results for the various logistic regression models. In the first model, I only included Function VHQMI as a predictor. Coefficients are reported as odds ratios, with values above one signaling a greater likelihood of an outcome and values below signaling a lower likelihood. The coefficient for Function VHQMI is positive but non-significant. Principals with Function VHQMI were 1.36 times more likely to implement improvement strategies than principals with Form VHQMI.

In the second model, I include district membership as a predictor. District C was used as the reference district because it had the fewest school leaders who implemented improvement strategies. School leaders in both District A and District D were approximately four times more likely to implement improvement strategies than school leaders in District C. This relationship holds for the remaining three regression models, with the odds ratio increasing by almost 50% for District A while only slightly increasing for District D. School leaders in District B were twice as likely to implement improvement strategies than school leaders in District C, but this result was not statistically significant. The coefficient for Function VHQMI increased by fifteen percent, from 1.36 to 1.56, but the coefficient is still not statistically significant. Additionally, the inclusion of district membership into the model increases the variance described, but the result is not statistically significant (LR $\chi^2(3) = 5.45$, $p = 0.14$).

In the third model, I included the categorical variable for years in current school. School leaders who were in their schools for more than four years were 4.47 times more likely to implement improvement strategies in relation to school leaders who are in their first or second year in their school ($p < 0.05$). School leaders who were in their schools for 3-4 years were slightly less likely to implement improvement strategies than those who were in their schools for 1-2 years, but this result is not statistically significant. There remained a positive relationship between Function VHQMI and implementation of improvement strategies, holding all else constant, but this result is still not statistically significant. Odds ratios for each district increased as well, with school leaders in District A and District D now approximately six times more likely to implement improvement strategies. The Likelihood Ratio test indicates that inclusion of principal experience in school is statistically significant ($\chi^2(2) = 5.74$, $p = 0.05$).

Table 18

Logistic Regression Results for Implementation of Improvement Strategies

	Function VHQMI Only	Inclusion of District	Inclusion of Experience	Inclusion of Taught Math
Function VHQMI	1.36	1.56	1.47	1.39
	0.66	0.54	0.51	0.51
District A		4.04*	5.55**	5.82**
		0.76	0.80	0.79
District B		2.08	2.92	2.61
		0.85	0.85	0.89
District D		4.91**	5.91**	4.72**
		0.72	0.72	0.70
3-4 Years in school			0.93	0.88
			0.66	0.66
>4 Years in school			4.47**	4.22*
			0.77	0.81
Taught Math				0.42
				0.60
N	71	71	71	71
Ll	-47.83	-45.11	-42.23	-41.04
chi2	0.41	6.96	10.88	11.06
P	0.52	0.14	0.09*	0.14

OR/SE, * $p < 0.10$, ** $p < 0.05$

In the final model, I included the binary variable for experience teaching math. After controlling for district membership, Function VHQMI, and experience in school, principals who had not taught mathematics were almost twice as likely to implement improvement strategies than those who did teach math. The LR test indicates that the inclusion of teaching math is not statistically significant ($\chi^2(1) = 2.39$, $p = 0.12$). Principals with a Functional VHQMI are now 1.4 times more likely to implement improvement strategies, which is a 10% drop from Model 2. Odds ratios decrease, and standard errors increase for experience in school. As a result, there is not a statistically significant relationship at the 0.05 level for principals who had been in their current schools for more than four years in comparison to principals who are in their first or second year at their school. In this final model, school leaders in District A were approximately six times more likely to implement improvement strategies than school leaders in District C. The odds ratio for school leaders in District D slightly decreases to 4.71, but the relationship is still significant at the 0.05 level. School leaders in B are still more likely than leaders in C to implement improvement strategies, and the result is still non-significant.

I assessed how accurately the logistic regression model the predicted school leaders implementing improvement strategies by conducting a classification analysis. I selected a cutoff value of 0.41 because 41% of the principals in this sample implemented improvement strategies. This cutoff value indicates that if the logistic regression model had a predicted probability greater than 0.41, then a principal would be predicted to implement improvement strategies. This predicted value was then compared to whether or not a principal implemented improvement strategies. Table 23 summarizes the results of the classification analysis. Overall, about 73% of results were correctly classified. About two-thirds of the school leaders who implemented at least one instructional improvement strategies were correctly classified, and about 80% of school leaders who did not implement any improvement strategies were correctly classified (Peng et al. 2002).

Table 19

Logistic Regression Classification Analysis

	Actual		
Predicted	**Implemented Improvement Strategies (A)**	**Did Not Improvement Strategies (A)**	**Total**
Implemented Improvement Strategies (P)	21	11	32
Did Not Improvement Strategies (P)	8	31	39
Total	29	42	71

Summary of Findings for Research Question 1

In summary, district membership was significantly related to the implementation of improvement strategies. The Function VHQMI measurement, although positive, was not statistically significant and did not change value with the inclusion of other variables. Also, school leaders' experience as an instructional leader in their current schools was positive, with school leaders who had more than four years in their current school about four times more likely to implement improvement strategies. Interestingly, school leaders who had math teaching experience were less likely to implement improvement strategies, when controlling for district membership, Function VHQMI, and experience in school.

These results indicate that district and school contextual factors have a greater influence on the implementation of improvement strategies than Function VHQMI alone. Although it might be important for school leaders to understand the functions of inquiry-oriented mathematics instruction, this does not lead to the implementation of instructional improvement strategies. How aspects of the school and district context influence instructional leadership will be investigated in the following section.

Findings and Analysis for Research Question 2

In this section, I report findings of how aspects of the district and school context influence the implementation of instructional improvement strategies. I compare four different sets of principals: Principals with Functional VHQMI who Implemented Improvement Strategies, Principals with Form VHQMI who Implemented Improvement Strategies, Principals with Function VHQMI who implemented Management Strategies, and Principals with Form VHQMI who implemented Management Strategies. These groups are based on principal VHQMI and the types of instructional leadership strategies implemented. As a reminder, principals for each group were selected because their interviews indicated that they coordinated current problems of learning and teaching as they had framed them with relevant strategies, whether that be from an instructional management or improvement orientation, and implemented strategies that accounted for multiple instructional leadership functions. I conclude my discussion of each group with a Summary section that elaborates on potential explanations for central findings.

Principals with Function VHQMI who Implemented Improvement Strategies

Stewart K-8, District A, Year 3. Stewart is a small K-8 school in District A that performed above district averages for all three grade levels on high-stakes summative assessments. In Year 3, MIST collected data for three of the four teachers in the math department. All three teachers in the MIST sample demonstrated expertise in inquiry-oriented math instruction as their lessons were categorized in the top two bands of instruction: Needs Help with Discussion (NHWD), and Ambitious. In addition to high student performance and teachers having expertise, the principal, Sam Dunning, reported that district leaders primarily held him accountable for improving mathematics instruction rather than improving student performance.

Importantly, Sam understood that teachers required significant support to develop ambitious instruction, which is a perspective that was potentially afforded by his functional understanding of inquiry-oriented mathematics instruction. He elaborated on how teacher development required multiple school years and sustained support from district leaders who provide high-quality professional development and curricular tools. Importantly, Sam's perspective on teacher development was in agreement with research on professional development (Borko 2004).

Key to Sam's development as an instructional leader was hiring Tammy Williams as a math teacher several years before the MIST study. By Year 3, Tammy had been promoted to district math specialist in District A. Sam reported that he observed instruction with Tammy when she was a math teacher and that these observations helped him understand how certain teacher moves supported student learning. Sam also reported observing Tammy's instruction, which helped him further understand how to identify key instructional moves that support students' conceptual development.

In Year 3 of the study, Sam reported working with Tammy and one of the math teachers in Stewart K-8 to identify which teachers needed additional support. In this work, Tammy identified that one of the math teachers needed support in maintaining the cognitive demand of instruction throughout investigations. Sam also added a second math class for struggling students that focused on developing mathematical concepts. Stewart was one of the only schools in my dissertation sample that used a second math class to support students conceptual learning rather than focus exclusively on developing basic skills.

M.C. Gable, District A, Year 3. This school was fresh-started in Year 1 of the MIST study, with the majority of the staff not hired back. The principal, Milt Bommie, was assigned to M.C. Gable in Year 1 based on his reputation as a school leader who could improve student performance. The school was still under intense pressure to raise test scores by Year 3 and was still one of the lowest performing schools in the district. Milt reported that he was held accountable for both improving test scores and improving the quality of instruction.

Despite low student performance, Milt viewed improving the quality of inquiry-oriented math instruction as crucial for improving student learning. To support math teachers, he pressed teachers through observation and feedback to develop both rigorous and equitable instruction. He noticed that some teachers would reduce the demand of math tasks for struggling students, which he attributed to teachers' beliefs about students' mathematical capabilities. To support math teachers in developing high expectations for all students, Milt brought in professional development in Year 3 that focused on sustaining the cognitive demand of math tasks, which is a key challenge for teachers who are developing ambitious instructional practices (Wilhelm 2014). Through this observation and feedback process, Milt demonstrated how he potentially used his understanding of inquiry-oriented mathematics to identify central issues in instruction and broker learning opportunities through PD that directly addressed an identified issue (e.g. maintaining the cognitive demand). Milt reported that he also observed instruction with the district math specialist, Tammy, several times throughout the year to improve his understanding of how to support math teachers. It is possible that these joint observations supported Milt in identifying central issues in teachers' inquiry-oriented mathematics instruction.

Additionally, Milt's professional experience shaped his perspective on supporting teacher learning and instructional improvement. Milt taught math for thirteen years before becoming a school leader. This experience might have shaped his understanding of inquiry-math instruction and instructional leadership, although it is not a certainty given that most math teachers require systemic, ongoing support to understand and develop ambitious instructional practices.

There was evidence of some instructional expertise in A5. In Year 3, MIST collected data for all three math teachers in the department. Researchers did not collect measures of expertise for one of the teachers because he was on military leave. The remaining two math teachers' lessons were categorized in the top two bands of instruction: NHWD and Ambitious. It was atypical for the MIST study to have such prevalence of instructional expertise.

Widmark, District A, Year 3. In Year 3, Widmark was one of the lowest performing schools in District A and was at Stage 5 under NCLB. The principal, Red Wenger, reported that he was primarily held accountable for both improving test scores and the quality of mathematics instruction. He discussed how the district had shifted expectations from principals being top-down managers to principals who were instructional leaders. He reported that this shift occurred after he had attended the Principal Institute in District A. The Principal Institute was a year-long program for principals in District A that offered training for aspiring and first-year principals. Training occurred throughout the school year and focused on communicating expectations to teachers as well as understanding the Principles of Literacy (PoL) for specific content areas. The PoL was part of the instructional infrastructure (e.g. language, instructional methods, instructional tools) implemented by districts that partnered with the Institute for Learning (IFL). None of the three principals from District A in this group reported attending the Principal Academy. Despite not attending the Principal Academy, the implementation of this training program could have signaled to experienced principals the increased importance of principal instructional leadership in District A.

There was evidence of limited expertise in Widmark. MIST collected data for all three middle school math teachers and only one teacher had instructional expertise. Additionally, the principal, Red, was in his first year at Widmark. Consequently, he reported that he invested significant amounts of time developing trust with teachers during his first year; he planned to press teachers more on their inquiry-oriented math instruction in the following school year.

Red had a sophisticated perspective on supporting math teachers' learning of inquiry-math instruction and implemented several instructional improvement strategies. Prior to becoming a principal, Red had been a math teacher and then a district-level math curriculum coordinator in District A. Potentially influenced by his background as a district specialist and math teacher, he reported that he hired math teachers based on teachers' ability to enact ambitious instruction, rather than only focusing on college degree or area of certification. Widmark is one of few middle schools in my dissertation sample that did not offer second math classes for struggling students. Red believed that good math instruction should eliminate the need for students to take a second math class that focused on basic skills, which is an interesting perspective given that the school was under intense pressure to improve its performance. Red reported that he observed math instruction with the school-based math coach to identify common issues that teachers faced in instruction and implement interventions to improve instruction. He elaborated that the coach worked primarily one-on-one with teachers who primarily had procedurally-oriented instruction.

Two Lagoons, District B, Year 4. In Year 4, Two Lagoons Middle performed close to district levels on state assessments. The school was also Stage 0 under NCLB. Consequently, both the principal and assistant principal reported that they were held accountable by district leaders for following the curriculum guides and improving mathematics instruction. Vera, the assistant principal in charge of the math department, reported that her principal pressed her to work closely with math teachers through observing instruction and providing feedback as well as assessing the needs of math teachers. Importantly, Vera had been a district math specialist and school-based math coach in District B before becoming an assistant principal. There was evidence throughout the MIST study that this assistant principal had the capacity to directly support math teachers' learning.

There was evidence of limited instructional expertise in Two Lagoons for Year 4. MIST collected data on the school-based math coach and five of the eleven teachers in the math department. The math coach and one of the five teachers had lessons in the top two bands of instruction. The remaining four teachers' lessons were categorized as Proceduralized, meaning that teachers selected cognitively demanding tasks but failed to maintain the cognitive demand throughout the course of a lesson (e.g. simplifying complex tasks by providing solution methods).

Vera reported implementing several strategies to support teachers in significantly reorganizing their practice. She assessed that most teachers didn't teach standards to an adequate depth, which agreed with the measures of expertise for teachers in Two Lagoons. Vera also worked closely with the school-based math coach to identify which individual teachers would need one-on-one support. Both Vera and the math coach conducted coaching cycles to support struggling teachers. Importantly, she also leveraged her prior work relationships at the district office to support math teachers' learning. She had the two district math specialists conduct observations and give feedback to math teachers at Two Lagoons throughout the school year. Overall, there was evidence that Vera leveraged her functional understanding of inquiry-mathematics instruction and prior work relationships to support teacher learning.

Perspectives on Improvement. Importantly, all four principals understood that teachers required intensive support sustained for multiple school years to develop ambitious instructional practices. There was also evidence that some of these principals understood that substantial teacher learning involved more than improving their content knowledge (Kazemi & Franke

2004; Cobb & Jackson 2011b). For example, Milt discussed the importance of equitable and ambitious instruction, mentioning that some teachers lowered the cognitive demand based on their views of their students' mathematical capabilities. Importantly, his observation aligns with issues math teachers commonly face when developing inquiry-oriented mathematics instruction (Wilhelm 2014). Additionally, Milt's noticing indicated that he took into account aspects of teacher learning, which are not measured on the VHQMI rubrics.

Professional Background and Professional Development Attended. All four principals had teaching experience, coaching experience, or professional relationships that could have supported their understanding of inquiry-oriented math instruction. Three of the four principals were math teachers before becoming principals, which does not necessarily indicate that they understood inquiry-oriented math instruction nor understood challenges teachers face when developing this instruction. Importantly, though, two of those principals were district math specialists who were responsible for developing the curriculum and supporting all math teachers' learning in some capacity. Additionally, all three principals with a background in mathematics mentioned in detail how they used observation and feedback to support instructional improvement, which is atypical for principals in the MIST sample and possibly in the broader K-12 landscape (Rigby et al. 2017). The fourth principal, Dunning, had a professional relationship with the district math specialist in District A. He hired Tammy as a math teacher prior to her becoming the district math specialist in District A. Sam reported that his observations of Tammy's instruction and joint observations with Tammy supported his understanding of inquiry-math instruction and helped him identify aspects of instruction that influenced student learning.

All three of the school leaders who described professional development reported attending at least one district-level professional development session that supported their instructional leadership practices in mathematics. Specifically, all three school leaders reported attending sessions focused on what to look for when observing an inquiry-oriented math lesson. All of these principals discussed in detail the importance of classroom observation and feedback, but it is unclear how, or if, these sessions influenced their capacity to give effective feedback to math teachers.

Accountability Pressures. There were no clear patterns between student performance and implementation of improvement strategies for these four schools. Two schools performed at or above district averages on state tests, and two schools performed far below district averages and were under pressure to raise test scores. Importantly, M.C. Gable was "fresh started" in Year 1 of the MIST Study, and had replaced all school leaders and the majority of teachers. M.C. Gable also received additional funding from the district for programs that could improve student performance.

Of the three school leaders who were asked about district leaders' expectations, all three school leaders reported that they were held accountable for supporting instructional improvement. Two of these school leaders, both in District A, reported also being pressed by district leaders to improve student performance. One principal, Milt, reported that he was assigned to M.C. Gable because of his reputation for turning schools around. Overall, there was no indication that pressure to raise test scores curtailed instructional improvement efforts in both schools that performed significantly below district averages.

Student Demographics. There was also no clear relationship between student demographics and implementation of instructional improvement strategies. Three of the four schools had more students who received FRL and had more ELs than their respective district averages. This is important to note because schools with a high percentage of students receiving FRL or who are

EL might need to spend both financial resources and time to provide supplemental services for students. However, there was no indication for this group of schools that additional services for students impacted the implementation of instructional improvement strategies. The fourth school, Stewart, had more white students, fewer students who received FRL, and fewer EL students than the District A average. This school was also one of the highest performing schools in the district. Given the variance in student demographics for the four schools in this group, there is no evident relationship between student demographics and implementation of instructional improvement strategies.

Identifying and Leveraging Expertise for Supporting Teacher Learning. Importantly, all four of the school leaders also discussed the importance of working with district math specialists to supporting teachers' learning. Importantly, district math specialists in District A and District D, member districts for this set of four school leaders, had all demonstrated the capacity to support teachers' learning. All four school leaders requested that their district math specialists observe math teachers' lessons, give feedback on current instruction, and identify common areas in which teachers needed support. In one example, Milt worked with Tammy and identified that some teachers had issues with proceduralizing cognitively demanding tasks. As a result, Milt set up a professional development session that focused on strategies for maintaining the cognitive demand during mathematical investigations. In another example, Red at Widmark reported that he observed math instruction with Tammy throughout the school year to improve his understanding of inquiry-oriented math instruction. He reported that these joint observations improved both what he focused on during observations and the content of the feedback.

In addition to collaborating with district math specialists, two of the school leaders, Red and Vera, discussed how they worked with their school-based math coaches to support instructional improvement. Similar to work with district math specialists, Red and Vera had ongoing discussions with their math coaches in which they identified common instructional problems. For example, Red reported that the school-based math coach primarily conducted coaching cycles with teachers who proceduralized tasks. Similarly, the school-based coach at Two Lagoons conducted coaching cycles with teachers in need of additional support; however, it was unclear in this case what instructional issues were identified.

Identifying and Leveraging Teachers with Instructional Expertise. There was only one reported instance of a principal identifying and leveraging a teacher with instructional expertise in this group. All four schools had at least one teacher who had the instructional expertise, and in two schools the majority of teachers in the MIST Sample had instructional expertise. However, only one principal, Dunning, discussed leveraging the expertise of a math teacher. In this case, Sam sought advice from an expert math teacher on common instructional issues in the school. He also reported that he observed this expert teacher to understand more on how productive whole-class discussions function to support student learning. He reported that these interactions and observations influenced the feedback he gave to math teachers.

Summary. Importantly, all school leaders in this group illustrated how effective school instructional leadership in mathematics encompasses more than a vision for classroom instruction. In addition to understanding some of the underlying functions of inquiry-oriented mathematics instruction, these leaders also described some of the key aspects of supporting teacher learning. For example, Sam understood that it took multiple years for math teachers to develop inquiry-oriented mathematics instruction and that teachers required sustained support from district leaders. Second, all four school leaders described brokering opportunities to support teacher learning through seeking out district math specialists. In turn, these math specialists either worked one-on-one with teachers or led professional development for groups of math teachers. Third, all four school leaders sought out multiple forms of support for math teachers, with three of the four principals working directly with teachers by providing relevant feedback on math teachers' instruction. There was evidence that these three principals had expertise to support math teacher learning directly, which was atypical of school leaders in the MIST study.

There was evidence that all four school leaders had professional experiences that could have significantly influenced their perspectives on how to support math teacher learning, which in turn likely influenced their capacity to recognize and leverage relevant expertise. Three of the four school leaders had taught mathematics, with two also having also worked as district math specialists who developed curriculum and district professional development for math teachers. The fourth principal, Sam, hired and collaborated with Tammy before she became the district math specialist. Sam reported that his interactions with Tammy significantly influenced his perspective on what constitutes as effective math instruction and how to support math teachers' learning. Importantly, the professional experiences of these principals would be difficult for district leaders to design at scale. That is, it would be impractical, if not impossible, to hire only former expert math teachers as school leaders or ensure that principals hired expert math teachers who could eventually become district level specialists. However, these findings point to the importance of incorporating a leadership model in which at least one person with relevant expertise, either at the district or school level, directly supports teacher learning. These findings also indicate potential goals for principal PD, such as supporting principals in understanding how effective inquiry-oriented mathematics instruction relates to student learning and the importance of working with and leveraging relevant expertise.

In sum, this group of principals demonstrated an understanding of teacher development that extended beyond the dimensions of VHQMI, brokered opportunities for learning through district specialists who likely had the greatest capacity to directly support teacher learning, and ensured that multiple supports were in place to support teachers' learning. These findings are consistent with findings in the teacher learning literature in that the principals with the greatest capacity were also the educators who most valued and sought out relevant expertise. That is, it is likely that they had developed a deeper understanding of the challenges associated with learning effective inquiry-oriented mathematics instruction and sought out relevant expertise to support teacher learning. This may not be the case for principals who have a less sophisticated understanding of VHQMI and teacher learning.

Principals with Form VHQMI who Implemented Improvement Strategies

Sun River, District B, Year 4. Sun River was under pressure to raise student proficiency rates on state assessments. This middle school only had two grade levels, 7th and 8th, and students in both grade levels performed below district averages on state assessments. The school was at Stage 4 under NCLB sanctions in Year 4. The principal, Petra, who was in her first year after working in the 6th-grade feeder school, reported that she was primarily held accountable for raising test scores. Potentially in response to pressure from district leaders to improve performance, Petra was agnostic on how teachers improved student performance. She discussed using instructional management strategies as well as instructional improvement strategies to improve student learning. The instructional management strategies included having staff produce student performance data reports to identify both students who needed remediation and standards with low student performance. Students who needed remediation were assigned to a second math class or received additional tutoring on basic skills. Petra pressed teachers to reteach standards with low performance. There was no indication that reteaching focused on supporting students' conceptual development.

To support instructional improvement, Petra worked with the school-based math coach and an external consultant to implement professional development that had the potential to support teacher learning. For example, Petra reported that the school-based coach observed that teachers rarely pressed students for justifications during whole-class discussions. In agreement with this observation, all four teachers in the MIST sample, out of 12 math teachers total, had lessons categorized as Proceduralized, indicating that teachers did not lead effective whole-class discussions. To support teacher learning, Petra brought in an external consultant who led a PD session focused on planning and enacting CMP2 investigations that pressed on students to justify their solutions.

Cypress, District D, Year 3. Cypress Middle was a Math-Science-Technology Magnet whose students performed better than the district average on state assessments in Year 3. Both the principal and assistant principal reported that they were under little pressure to improve student performance on state assessments. Albert, the assistant principal who was in charge of the math department, reported that he was expected to work with both school and district coaches to bring in "high-quality" PD for math teachers. There was also evidence of instructional expertise in the school. MIST had data for five of the nine math teachers. Three out of the five teachers in the MIST sample had lessons categorized in the top two bands of instruction (i.e. NHWD, Ambitious). Overall, staff at Cypress were under less pressure to improve student performance, and a few math teachers demonstrated instructional expertise.

School leaders at Cypress discussed implementing multiple strategies for supporting teacher learning. The principal and assistant principal made sure that all math teachers had attended CMP2 PD by Year 3, which was atypical in the MIST study. This week-long summer professional development provided teachers with multiple opportunities to engage in pedagogies of investigation and enactment as they planned investigations with student thinking in mind. This professional development was also led by math educators who have the capacity to support teacher learning. Additionally, the principal, assistant principal, and school-based math coach regularly observed math classrooms together. The assistant principal reported that these joint observations helped school leaders communicate consistent expectations for math teachers' instruction, and identified teachers who were struggling with inquiry-oriented mathematics instruction. Consequently, the school-based math coach conducted coaching cycles to support struggling teachers; however there was no evidence on the content of these cycles. Importantly, the coach's MKT and VHQMI scores indicate that she had expertise in inquiry-oriented mathematics instruction, which increases the likelihood of her having the capacity to support teacher learning directly.

In Year 3, all school leaders in District D attended a PD series that had the potential to improve principals' VHQMI and instructional leadership in inquiry-oriented mathematics. Albert, Tamara, and Connie all attended this PD series, with the latter two school leaders to be discussed in the upcoming school summaries. The MIST Principal PD consisted of three monthly half-day sessions that followed the principles of design-based research (Boston et al. 2016). Two of the PD's central learning goals were to support principals in distinguishing between high and low cognitive demand tasks and improve principals' capacity to provide feedback on central aspects of inquiry-oriented mathematics instruction. A follow-up analysis of this design-based PD series found that principals overall had increased their capacity to distinguish between high and low cognitive demand tasks and increased their ability to identify teacher moves that aligned with inquiry-mathematics.

Birch, District D, Year 4. The staff at Birch were under pressure from district leaders to improve test scores as the school performed below district averages for all three grade levels on state assessments. Accordingly, the principal, Tamara, reported that district leaders primarily held her accountable for raising test scores. Similar to Petra in District B, Tamara reported that her staff generated student performance data reports to identify which students needed the most assistance. These reports were used to identify which students received additional instruction to improve performance on procedurally-oriented assessments.

Importantly, there was evidence that some of the teachers had instructional expertise at Birch. MIST collected data on four of the eight teachers in the math department. Two of these teachers had lessons rated as NHWD or Ambitious. Importantly, Tamara reported that most math teachers struggled with inquiry-oriented math instruction because they only had one or two years of teaching experience. Tamara's assessment is in some agreement with MIST data. It is possible that the teachers who did not participate in the MIST study struggled more with inquiry-oriented mathematics instruction. The MIST study made efforts to mitigate sampling bias by recruiting teachers based on randomization methods.

Tamara reported that she brokered opportunities for teacher learning through school-level professional development, professional development external to the school, and interactions with district math specialists. Similar to Cypress, Tamara sent all of her math teachers to CMP2 PD. As a second strategy, Tamara had ongoing discussions with the district-based math coach, Kacey, to identify which math teachers needed additional assistance. Consequently, Kacey led

PD at Birch that focused on analyzing student thinking in relation to challenging math tasks. Tamara reported that she also had conversations with Barbara, a district math specialist, to more deeply understand what to look for when observing math lessons and how teachers can more effectively use the assessments built into the CMP2 curriculum.

Magnolia, District D, Y4. Magnolia Middle School was under intense pressure from district leaders to raise test scores. Additionally, this school served a diverse student body, with the principal, Connie, reporting that twenty-five languages being spoken in Magnolia. She also reported that Magnolia was one of the lowest-performing middle schools in the state and that the twenty-two NCLB performance targets to meet.

Despite intense pressure to improve test scores, Connie reported that improving the quality of instruction was her vision for improving student learning. Connie helped broker several professional development sessions throughout the school year that had the potential to support substantial teacher learning, such as PD on facilitating high-quality student discussions throughout an investigation. Additionally, math teachers at Magnolia consistently reported that the principal pressed them to implement ambitious and equitable instruction.

Also, there was evidence that some of the teachers in the MIST sample had expertise in inquiry-oriented math instruction. The MIST study collected data for five of the nine math teachers. Three of these math teachers had lessons categorized as NHWD or Ambitious. There was also evidence that the school-based coach had expertise in inquiry-oriented mathematics instruction, which was important. Importantly, though, there was some tension between the math coach and the teachers because Connie positioned a teacher as a source of instructional expertise, rather than the school-based math coach. Interestingly, Connie's assessment was congruent with measures of expertise.

Perspectives on Improvement. All four school leaders in this group brokered learning opportunities for math teachers through school-level professional development. This professional development was either led by external consultants or school-based math specialists. Furthermore, all four school leaders in this group either sought out district based math specialists, district math coaches, or school-based math coaches to understand more about current math instruction how teachers could better facilitate student learning.

Two of the four principals in this group, Petra and Tamara, implemented both improvement and management strategies to support student learning. The other two principals in this group did not discuss implementing instructional management strategies. Petra and Tamara described how staff produced data reports for each student to identify areas of low performance and then focused on low-performing students or standards with low student performance. There was no evidence in both principals' reports or SSFs that such data analysis activities aimed to identify connections between prior instruction and evidence of student learning, or aimed to identify strategies to support students in developing conceptual understandings of key content.

Professional Background and Professional Development Attended. Overall, it is unlikely that the principals' teaching experiences would have supported a functional understanding of inquiry-oriented mathematics. Three of the four principals (Petra, Tamara, Connie) with Form VHQMI who implemented improvement strategies had teaching backgrounds that were not in mathematics or inquiry-oriented mathematics (e.g. background as high school social studies teacher). Only one principal, Albert at Cypress, had a background in mathematics. He majored in math and taught high school math, which likely supported his understanding of middle school math content; however, teacher reports of his feedback indicated that he did not focus on salient aspects of inquiry-oriented mathematics instruction when observing teachers (e.g. focused on student engagement). It is unlikely that Albert had the capacity to support teachers directly in developing ambitious instructional practices.

Importantly, all four principals reported attending professional development that had the potential to develop their understanding of inquiry mathematics and improve their instructional leadership. As described previously, all three principals in District D attended the MIST Principal PD in Year 3 (Boston et al. 2016). All three principals reported that these sessions influenced what they looked for when observing math lessons. One principal, Connie, reported that it changed how she evaluated math teachers' instructional expertise. Connie examined math teachers' lessons plans for evidence of quality before attending the MIST principal PD sessions; after, she assessed how teachers implemented math tasks and facilitated math explorations to determine instructional quality. This shift, from assessing lesson plans to observing substantial classroom interactions to determine instructional quality, is important and non-trivial given that it focuses on students' opportunities to learn. Additionally, it is unclear how lesson plans can be enacted, which is important to consider given that many teachers struggle to maintain the cognitive demand of high-quality math tasks (Garrison, 2014).

The fourth principal, Petra at Sun River, reported two key professional experiences that had the potential to support her understanding of inquiry-oriented mathematics instruction. She attended CMP2 PD before Year 4 when she was an assistant principal. Petra reported that this training helped her understand how similar concepts are taught across grade levels with increasing sophistication in the later grades. Additionally, before Year 4, Petra worked with Jenni when she was a math teacher in her school before advancing to her role as a district math specialist. Petra reported that this professional relationship supported her understanding of what to look for when observing inquiry math lessons. Petra still sought out Jenni for support in Year

4 when Jenni was a district math specialist. Petra stated that this professional relationship also helped her establish connections with other district leaders in the mathematics department, some of whom had visited her school to observe math instruction and provide feedback to teachers.

Accountability Pressures. Three of the four schools in this quadrant were under significant pressure to improve test scores and meet NCLB performance targets. One of these schools, Magnolia in District D, was under threat of reconstitution. All three principals in struggling schools (Petra, Tamara, Connie) reported that they were primarily held accountable for raising test scores. Despite this pressure, all three principals mentioned the importance of using instructional improvement strategies for improving student learning, although two of these principals, Petra and Tamara, also used instructional management strategies to improve student performance. The fourth school, Cypress Middle, performed better than district averages on state tests.

Student Demographics. There were no evident relationships between student demographics and principal instructional leadership for this group of schools. All four schools had similar race demographics to their respective district averages. One school, Magnolia Middle, had more EL students than the district average. There was no indication, though, in principal interviews or teacher interviews how the staff responded to meeting the needs of ELs. Two schools served more students receiving FRL than the district average. Overall, there was no reports from this group of principals that elaborated on how student demographics influenced the academic support that students received or the training that math teachers received.

Identifying and Leveraging Expertise for Supporting Teacher Learning. All four school leaders worked with either school coaches, district math coaches, or district math specialists to diagnose instructional issues and provide supports for teacher learning. This finding indicates that these principals understood the challenges that teachers face when learning ambitious instruction, valued ambitious instruction, and sought out expertise to support teacher learning. Three school leaders (Petra, Tom, Tamara) sought out either math coaches or math consultants to understand how to support teachers in significantly reorganizing their instructional practice. It is important that principals leveraged school-based math coaches with expertise given that there were many instances in the MIST study where school leaders directed the work of the school coach in ways that did not align with instructional improvement (e.g. required the coach to produce data reports). In one example, Tamara at Birch described how she worked with the coach to support teacher learning. Tamara reported that Kacey led monthly "mini lesson studies" that focused on planning lessons with high cognitive demand and anticipating potential student misconceptions.

Two of the four principals with Form VHQMI who implemented improvement strategies sought out district math specialists to support teacher learning. In one case, Petra at Sun River coordinated visits with multiple district math specialists in which they observed teachers, gave feedback to teachers, and met with Petra to discuss strategies for supporting teacher learning (e.g. coaching, professional development, etc.). Petra also reported that math teachers had participated in a PD session that focused on developing teacher questions that would press students to articulate their mathematical reasoning; it is unclear, though, if this PD was a direct result of the visits by the district math specialists.

As mentioned, two of the principals in District D, Tom and Tamara, brokered professional development opportunities with an external agency. These principals ensured that all of their teachers attended CMP2 training at Michigan State. Although available to all schools in District D, only two school leaders in this analysis described this training as a key support for math teachers. This finding indicates that both Tom and Tamara understood, to some extent, the learning demands placed on teachers who were developing ambitious instruction and viewed the CMP2 PD as an effective strategy for supporting teacher learning.

Identifying and Leveraging Teachers with Instructional Expertise. In three of the four schools in this group (Cypress, Birch, and Magnolia), at least two of the teachers in the MIST sample had lessons categorized in the top two bands of instruction, which was atypical for my dissertation sample. The presence of teachers with instructional expertise in schools had the potential to help principals assess current instructional practices by observing differences in instructional quality across multiple classrooms. In the fourth school, Sun River, there was no evidence of expertise in the MIST sample, which highlights the importance of Petra seeking out instructional leaders with relevant expertise.

There was evidence that the principal at one school, Magnolia in District D, identified and leveraged a math teacher with instructional expertise. Interestingly, Connie accurately assessed that the math coach did not have expertise in inquiry-oriented mathematics instruction. Consequently, Connie directed math teachers to work with a teacher who had expertise as measured by IQA and MKT, indicating that Connie both valued inquiry-oriented mathematics instruction and had some capacity to identify key differences in instructional quality. This finding is important given that she did not have a functional VHQMI. It could indicate that having a Function VHQMI was not a requirement to identify salient differences in instructional quality.

Summary. Importantly, all four school leaders discussed working with school-based coaches or district math specialists who could directly support teacher learning. All four school leaders reported that they attended PD that had the potential to support their work as instructional leaders in mathematics, with three of those attending the MIST Principal PD in District D. These two findings indicate that it is not necessary for principals to understand the underlying functions of inquiry-oriented math instruction to value effective inquiry-oriented mathematics instruction, conceptualize student learning in different ways, and understand that teachers need extensive support in developing ambitious instructional practices.

Two key differences emerged between the two groups of principals who implemented instructional improvement strategies. First, there was no evidence that principals with Form VHQMI had the capacity to support teacher learning directly. In contrast, three of the four principals with Function VHQMI worked directly with teachers on aspects of inquiry-oriented mathematics instruction. Second, none of the principals with Form VHQMI described characteristics of teacher learning in detail, whereas all four principals with Function VHQMI elaborated on how teachers develop ambitious instructional practices. As indicated in the previous paragraph, it was likely that principals with Form VHQMI valued inquiry-oriented mathematics instruction, understood that it required significant teacher learning, and recognized the expertise of colleagues who could directly support teacher learning. This group of principals, though, did not elaborate in detail how to support teacher learning nor had they have the capacity to support teacher learning directly.

Principals with Function VHQMI who Implemented Management Strategies

Colman, District A, Year 3. The principal, Devin, reported that district leaders primarily held her accountable for raising test scores. This school was one of the lowest performing schools in District A for Year 3. Devin also said that she had applied for and had received a school improvement grant from the state to improve student performance. She used the grant to hire a school-based math coach whose primarily responsibility was to produce student performance reports for teachers. These reports were in turn used to identify which students need additional tutoring. There was no evidence that the school improvement grant was used to support the implementation of instructional improvement strategies. Despite efforts to turn the school around, Colman Middle was reconstituted at the end of Year 3.

In Year 3, MIST collected data for two of the three math teachers in the school, and there was some evidence of expertise. One of the two math teachers in the MIST sample had a lesson categorized as Ambitious, while the other teacher's lesson was categorized as Traditional. Additionally, the math coach's VHQMI was functional, and her MKT was one s.d. above the normed mean, indicating that she potentially had expertise in inquiry-oriented math instruction. However, as previously noted, she primarily conducted instructional management strategies. Importantly, Devin did not mention leveraging the expertise of the school-based math coach or of the math teacher who had developed sophisticated instructional practices.

Devin described several different instructional management strategies for improving student performance. She expected for teachers to "own the data" and identify which students needed to be placed in additional math classes that focused on reteaching basic skills and targeted tutoring. Devin also described how the staff used monthly professional development to analyze student performance on assessments, color-code students based on levels of proficiency, and plan reteaching strategies.

There was some indication that Devin's functional understanding of inquiry-oriented mathematics instruction shaped her instructional leadership. She expected teachers to use math tasks that had multiple solution paths to support students in developing a robust understanding of math concepts. Additionally, Devin reported that she sought out advice from the district math specialist on what to look for when observing math lessons. However, both math teachers in the sample reported that they were held accountable for raising test scores. Additionally, teachers reported that Devin's post-observation feedback focused on posting clear lesson objectives and student engagement rather than aspects of inquiry-oriented mathematics instruction.

Green Springs, District B, Year 3. Reports from the principal and teachers at Green Springs indicated that district leaders held the staff accountable for improving student performance on state assessments. The principal, Mary, reported that district leaders expected her to "… get off all of the lists," meaning that all sub-populations of students should meet proficiency targets. Green Springs was at Stage 5 under the NCLB framework in Year 3, which meant that it had not made AYP for at least six years. Mary explained that although the school had not attained AYP in Year 2, a value-added model of student achievement indicated that students at Green Springs had the most growth in math performance in the district.

There was some evidence of instructional expertise in Green Springs. Two of the four teachers in the MIST sample had lessons categorized as NHWD. However, the remaining two teachers in the sample and the school-based math coach had lessons categorized as Traditional or Procedurlaized. Measures of expertise also indicated that the math coach had less expertise than some of the math teachers in Green Springs. Also, the coach returned to teach full time during Year 3 because the school was unable to hire a sufficient number of full-time math teachers and this constrained her work with teachers.

Mary provided limited evidence that her functional understanding of mathematics instruction influenced her instructional leadership as she described implementing several instructional management strategies to raise test scores. The math department primarily used teacher collaborative time to compile data from multiple assessments (e.g. school-generated assessments, district benchmarks, state tests) to track student performance and categorize students. Students who were close to proficient (i.e. bubble kids) received additional support in the form of a second math class and targeted tutoring. Evidence from the principal interview indicated that the additional instruction and tutoring focused on developing basic skills.

There is some indication that Mary's understanding of inquiry-oriented mathematics instruction influenced who she sought out to support math teachers. She described bringing in one of the district math specialists to lead a session that focused on higher order questioning in math lessons. Teacher interviews, though, did not provide enough detail to determine if it pertained to inquiry-oriented mathematics instruction. The criteria for what constituted higher order questions was unclear. Higher-order questions in content-general frameworks (i.e. Bloom's Taxonomy, Webb's Depth of Knowledge) are not necessarily aligned with higher-order questions in ambitious math instruction. It is important to note that the district math specialist who led the PD session, Jenni, had expertise in supporting math teachers' learning and was a strong advocate for ambitious math instruction. It is possible that the PD session focused on an inquiry-oriented operationalization of higher-order questions, but there was insufficient data to draw that conclusion.

Creekside, District B, Year 4. Creekside Middle was one of the highest performing middle schools in District B in Year 4. Consequently, the assistant principal, Ross, reported that he was not under pressure to improve test scores. The principal reported that district leaders primarily held him accountable for pressing teachers to use CMP2 and follow pacing guides in the district's curriculum frameworks. However, both the principal and assistant principal focused on implementing instructional management strategies with the aim of improving test scores. Ross helped facilitate teacher collaborative meetings. He reported that these meetings focused primarily on analyzing student performance data to understand what content needed to be retaught and to identify students who needed additional tutoring. Evidence from the teacher interviews indicated that these interventions focused on supporting students in developing basic skills. Ross viewed it as important to support math teachers in developing statistical literacy and analyzing student performance data critically. However, there was no indication that he had problematized supporting mathematics teachers in developing inquiry-oriented mathematics instruction.

There was some evidence of instructional expertise in Creekside. Of the four teachers in the MIST sample, one conducted a lesson categorized as NHWD. Additionally, the VHQMI of school-based math coach was functional and her MKT score that was one s.d. above the mean. Importantly, though, the assistant principal and the principal did not leverage her instructional expertise. Instead, the assistant principal directed her to organize math tutoring, produce student performance reports, and organize Saturday camps for students who were not "Proficient" on state assessments. Furthermore, Ross positioned the math teacher with high test scores as a source of expertise, thereby limiting the extent to which teachers turned to the school-based math coach for advice. Although Ross had some functional understanding of inquiry-oriented mathematics instruction, there was no indication that this understanding influenced his instructional leadership.

Baldwin, District C, Year 4. Although Baldwin Middle met AYP targets at the end of Year 3, the school was still at Stage 4 under NCLB. Consequently, the principal, Bobby, reported that district leaders' evaluations focused on "Whether I pass the test, whether these students pass the test." The principal also clarified that improving the performance of low-achieving African-American was a high priority. To achieve this goal, he had brokered professional development for teachers that focused on how to support African American students in the classroom, but the focus of this PD was not addressed in either his interview or in teachers' interviews. Bobby further clarified that the school had trouble hiring full-time math teachers, which resulted in larger class sizes.

There was no evidence that any of the three math teachers or the school-based coach in the MIST had developed expertise in inquiry-oriented mathematics instruction. All three teachers' lessons were categorized as Traditional, and all three had negative MKT scores. The math coach's VHQMI and MKT scores were greater than the math teachers in her building, indicating that the coach had relative expertise. However, the principal directed the work of the coach towards administrative tasks, such as preparing lesson materials for teachers.

Although Bobby had a functional VHQMI, there was no indication that this influenced the problems he identified in mathematics instruction or the strategies implemented to support teacher learning. The principal gave primacy to instructional management strategies for improving student performance. He reported that classes were tracked by student performance on the previous year's state assessment. Students who were close to proficient at the end the previous school year were placed in an additional math class that focused on developing basic skills. The math department typically met four times a week, but these meetings focused primarily on implementing instructional management strategies (e.g. data analysis to regroup students for reteaching).

Perspectives on Improvement. Although all four of these principals had a Function VHQMI, there was little evidence that this understanding of mathematics instruction significantly influenced their instructional leadership. All four school leaders with Function VHQMI who implemented instructional management strategies focused on providing low performing students with additional, procedurally oriented instruction to meet NCLB proficiency targets. Additionally, three of the four school leaders did not discuss math teachers' current instruction as it related to inquiry-oriented mathematics. From this group, only Devin identified instructional issues as they related to inquiry-oriented math instruction (e.g. some teachers proceduralize tasks); however, she did not discuss implementing instructional improvement strategies to address these issues. Findings for this group of principals indicate that school leaders need to know more than the underlying functions of inquiry-oriented math instruction to view inquiry-oriented math instruction as effective for supporting student learning. Also, a Function VHQmI does not necessarily elaborate on how principals think about supporting teachers who are developing ambitious instructional practices.

Professional Background and Professional Development Attended. None of the school leaders with Function VHQMI who implemented management strategies had experience teaching either inquiry-mathematics or mathematics in general. Their teaching experience ranged from middle school social studies to social work to high school science. Furthermore, none of the principals in this group discussed professional relationships with district math specialists or other educators with expertise in inquiry-oriented mathematics instruction. In contrast, some of the principals who implemented improvement strategies described longstanding relationships with district math specialists.

None of the four principals reported attending professional development that had the potential to either support their instructional leadership in inquiry mathematics or enhance their understanding of inquiry-oriented mathematics. Two of the four principals, Devin and Mary, attended professional development sessions that focused on pacing guides and other curricular tools in mathematics; however, there was no indication that this PD had the potential to enhance their understanding of mathematics instruction.

Accountability Pressures. Although only two of the four schools in this group performed below district averages, all four school leaders reported that they were primarily held accountable for improving student test scores. Both low-performing schools, Colman in District A and Green Springs in District B, were at Stage 5 under NCLB, which indicated that these schools were required to either offer school transfer options for students or provide supplemental supports such as additional instruction or tutoring. It is, therefore, likely that NCLB sanctions influenced the extent to which the principals of these two of the schools could have implemented instructional improvement strategies. Interestingly, both Devin and Mary were the only principals in this group who communicated instructional expectations related to inquiry mathematics or brokering PD with district math specialists. Thus, high pressure from district leaders to raise test scores does not inherently curtail instructional improvement efforts, but it may influence the degree to which principals place emphasis on student performance on procedurally-oriented assessments.

Student Demographics. Student demographics for three of the four schools in this group were similar to district averages, indicating that they were serving students with typical needs in their respective districts. Creekside Middle had far fewer EL students (5%) than the district average (30%). As a result, Creekside used fewer resources to support EL students in their school than was typical for schools in District B, such as hiring additional EL teachers or orienting instruction towards ELs. However, as identified in prior research, teachers who teach mathematics through discourse can support ELs in participating in mathematical investigations, particularly if the focus is on developing mathematical arguments rather than developing vocabulary (Moschkovich 1999). Thus, having fewer EL students may free up financial resources for the school, but it won't necessarily enable supports for teacher learning to be put in place.

Identifying and Leveraging Expertise for Supporting Teacher Learning. Although all four schools had school-based math coaches, there were indications that the coaches' work was unlikely to support teachers in developing inquiry-oriented instructional practices. In three of the four schools, math coaches were primarily responsible for producing student performance reports and assisting teachers in planning interventions (Colman, Green Springs, Creekside). Furthermore, shortages in full-time math teachers in Green Springs and positioning of the coach by the principal the coach at Green Springs also constrained the work of math coaches in their respective schools. As found in several other studies, school conditions or principal instructional leadership can limit the influence of math coaching (Matsumura et al. 2009; Mangin 2007).

Overall, it was unclear if principals' advice-seeking interactions with district math specialists had the potential to support substantial teacher learning. Two school leaders (Devin, Mary) sought out assistance from district math specialists, but the description of these interactions was insufficient to determine how it related to inquiry-oriented mathematics instruction. Devin turned to the district math specialist to learn more about what to look for when observing mathematics instruction. The second principal, Mary, brought in Jenni to facilitate a professional development session that focused on using higher-order questions in investigations, which, as previously discussed, does not necessarily relate to inquiry-oriented mathematics instruction. Given the expertise of Jenni, it is possible that the PD session had the potential to support teachers in substantially reorganizing their instructional practice.

Identifying and Leveraging Instructional Expertise. There was no indication that any of the four principals identified or leveraged instructional expertise in inquiry mathematics. Although instructional expertise appeared to be limited in three of the four schools, none of the school leaders discussed working with teachers who had the instructional expertise to support the math department. However, one principal discussed leveraging teacher expertise in data analysis with the aim of improving student performance on procedurally-oriented assessments.

Summary. In contrast to the two groups of principals who implemented improvement strategies, there was little indication that principals with Functional VHQMI who implemented management strategies recognized and attempted to leverage the expertise of accomplished teachers, school-based math coaches, or district math specialists to support teacher learning. Three of the four principals directed school-based math coaches to implement management strategies primarily, and the fourth coach primarily conducted administrative tasks (e.g. making announcements from the district, passing out supplies). Also, the work of two math coaches was limited due to shortages of math teachers and positioning by the principal. Two principals reported that they sought support from district math specialists; however, it is unclear if these advice-seeking interactions resulted in productive learning events for math teachers. In contrast, all eight principals who implemented improvement strategies sought advice that could support teachers' development of ambitious instructional practices. All eight of these principals described working with their respective district math specialists in ways that had the potential to support significant teacher learning, and six discussed the work of the school-based coach in ways that had the potential to support instructional improvement.

One potential factor that could have influenced this group of principals was the lack of PD that addressed instructional leadership for inquiry-oriented mathematics. None of the four principals reported attending relevant content specific professional development, whereas all four school leaders with Form VHMQI who implemented improvement strategies attended such training. Thus, the nature of principal professional development could have influenced how principals with Function VHQMI leveraged their understanding of inquiry-oriented mathematics. That is, if principals aren't supported in understanding how to orient towards teachers' instructional practices, then principals might not have the capacity to relate their understanding of a given content area to supporting teacher learning.

The implementation of instructional improvement or instructional management strategies might have also been influenced by the extent to which teachers in the principals' schools had developed ambitious instructional practices. The instructional expertise of the teachers in the MIST sample varied significantly for the different groups of principals. There were more teachers with expertise in schools where principals implemented improvement strategies than in the four schools of principals with Function VHQMI who implemented management strategies. Importantly, over one-half of the teachers in the MIST sample who taught in schools with improvement strategies had lessons rated in the top two bands of instruction. For the schools of principals with Function VHQMI who implemented management strategies, about a third of the teachers in the MIST sample had lessons in the top bands of instruction, whereas fifty-percent of teachers conducted Traditional lessons. It is possible that the teachers who were not sampled had greater instructional expertise than sampled teachers; however, teachers were selected randomly for participation to mitigate against selection bias. One potential explanation for this finding is that there were statistically significant differences in instructional expertise by district, with both District A and District D having more instructional expertise than District B and District C. Additionally, six of the eight schools that had improvement strategies were located in either

District A or District D. While selecting my sample for the second research question, it was challenging to find schools in District B and District C that met the sample selection criteria for schools with improvement strategies.

Although all four principals in this group described some of the functions of inquiry-oriented mathematics instruction, there were only a few instances in which their understanding of instruction appeared to influence their instructional leadership. Understanding the functions of inquiry-oriented mathematics instruction might be helpful for principal instructional leadership, but it does not necessarily indicate that principals value inquiry-oriented mathematics instruction and, in turn, leverage relevant expertise to support teacher learning directly.

Principals with Form VHQMI who Implemented Management Strategies

Park Falls, District B, Year 3. Although Park Falls performed close to district averages on state assessments, the principal and teachers reported that they primarily focused on improving test scores. The principal, Sarah, reported that district leaders held her accountable for improving student performance. She elaborated that it was particularly pressing to raise scores and meet proficiency targets for the African-American subpopulation.

Given the MIST sample of five teachers out of seven total, there is evidence of only limited expertise in inquiry-oriented math instruction in Park Falls. One teacher had a lesson categorized as Ambitious, but the remaining four teachers in the sample had their lessons categorized as Proceduralized or Traditional. Also, four out of the five teachers had negative MKT scores relative to the national mean. Furthermore, reports from school members indicated that the school-based math coach was unlikely to support teacher learning. The coach was only in her second year as an educator and was selected for this position because she was the only returning teacher who was interested. Furthermore, the principal often directed her work by requesting that she prepared materials for the state assessment and produced student achievement reports.

At Park Falls, the principal implemented several instructional management strategies aimed at improving student achievement. Teachers at Park Falls reported that they used teacher collaborative time to analyze student achievement data to primarily identify “bubble kids.” These students then received additional instruction and tutoring that focused on developing basic skills. For example, “bubble kids” were placed in a second math class that focused on basic skills. This phenomenon is common throughout schools that are pressed to meet NCLB performance targets (Booher-Jennings 2005).

Cesar Chavez, District C, Year 4. Although Cesar Chavez Middle performed close to district averages on state assessments for math, the principal and teachers reported that district leaders held the school accountable for improving test scores. The principal clarified that the district leaders emphasized improving student performance for struggling African-American students as well as English Learners. The principal, Barry, nor any of the teachers, elaborated on specific strategies for supporting low-performing African-American students. The student body at Cesar Chavez was 95% Latino in Year 4, which was greater than the district average of 68% Latino students. However, the percentage of ELs in Cesar Chavez (41%) was comparable to the district average in Year 4 (38%). To support ELs, teachers in Cesar Chavez Middle participated in several professional development sessions that focused on strategies for teaching vocabulary. Teachers reported that it was helpful to share strategies for teaching vocabulary, but there was no indication that the PD sessions significantly improved their instruction.

There was evidence of only limited expertise in inquiry-oriented mathematics instruction at Cesar Chavez. In Year 4, Cesar Chavez had ten total teachers in the math department, with five of those participating in the MIST Study. One teacher out of the five math teachers in the MIST sample had a lesson categorized as NHWD, with the remaining four teachers' lessons categorized as Proceduralized or Traditional. Four out of the five teachers and the school-based math coach MKT had scores lower than the national average for middle school math teachers. These measures of expertise were consistent with the principal's report that the majority of the math teachers were inexperienced and struggled with both teaching effectively and managing the classroom. Also, the school-based math coach only had experience at the elementary level and was not positioned by the principal as a support for teacher learning. Thus, there was limited evidence of instructional expertise in Cesar Chavez, and it was unlikely that the coach could support math teachers in developing ambitious instructional practices.

The principal at Cesar Chavez primarily implemented instructional management strategies to improve student learning. Similar to Park Falls in District B, struggling students were placed in a second math class and received additional tutoring that focused on developing basic skills and mathematical procedures. Despite pressure to improve student performance for African American students and ELs, there was no indication that these students received effective inquiry-oriented mathematics instruction.

C. Wright Mills, District C, Year 3. C. Wright Middle was one of the lowest performing schools in District C in Year 3. The assistant principal, Kendra, who was in charge of the math department reported that the district leaders held her and the principal accountable for improving test scores. The school was Stage 5 under NCLB, which could potentially result in school reconstitution continued to not AYP. C. Wright Mills served primarily low SES students as ninety-six percent of the students received FRL in Year 3, which was greater than the district average of eighty-seven percent.

There was also evidence of limited expertise in inquiry-oriented instruction in C. Wright Mills for Year 3. This school had a large math department, with six teachers in the MIST Study out of nineteen total. Four out of the five teachers in the MIST sample had lessons categorized as Traditional or Proceduralized, with one teacher not having IQA data. There was also evidence that the physical layout of the school inhibited the formation of teacher networks. Math teachers' classrooms were located in portables (e.g. single unit classrooms) outside of the main building, which made some of the math teachers isolated from their peers. Physical isolation of math teachers was a unique issue for C. Wright Mills and was not discussed as a factor for impeding the development of advice-seeking networks in other schools.

Kendra primarily described implementing instructional management strategies to raise test scores. She described how teachers used data from the state assessments and school-made assessments to form three tiers of intervention (i.e. Response To Intervention (RTI)). Students who were categorized in the bottom two tiers attended an additional math class and received additional tutoring that focused on basic skills.

Laurel, District D, Year 4. The school leaders and teachers in Laurel Middle were under pressure from both district leaders and the State Department of Education to improve test scores. Laurel Middle was one of the lowest performing schools in its state in Year 4 and was reconstituted at the end of Year 3. Reconstitution resulted in replacing all administrators and the retention of only one-third of the teachers. The principal, Bill, reported that he was expected to improve test scores significantly. Laurel Middle received additional resources from the state and district to improve performance. The school had both a school- or district-based coach and a state coach in each of the four core content areas. Although there were two math coaches in Laurel, reports from the principal, assistant principal, and school-based math coach indicated that the work of the two math coaches was not in conflict. Bill expected for both coaches to produce student data performance reports and to observe teachers and provide feedback to teachers. Additionally, Laurel Middle was in its first year of transitioning from a neighborhood school to a visual and performing arts magnet school in Year 4. The transition started at the 6th-grade level and would be expanded by one grade-level each year. In sum, Laurel underwent significant transformation through school reconstitution and magnet school transition.

In Year 4, there was evidence of only limited instructional expertise in Laurel. The MIST sample contained all five teachers in the math department. One of the five teachers had a lesson categorized as Ambitious, with the remaining teachers having lessons categorized as Traditional or Proceduralized. Importantly, there was evidence that the school-based coach could potentially support teacher learning. The school coach had a functional VHQMI as well as an MKT score that was one s.d. above the national mean. The school coach had assessed that the majority of teachers struggled with inquiry-mathematics instruction and often proceduralized lessons, which agreed with MIST measures of the quality of the teachers' instruction. The school-based coach reported that he conducted coaching cycles with several teachers, which typically involved solving math tasks with teachers and anticipating students' potential responses. Importantly, the principal and the assistant principal did not mention coaching cycles or improving inquiry-oriented mathematics instruction as key strategies for improving student learning. There was no evidence that the principals recognized or leveraged the expertise of the school-based math coach.

The school leaders at Laurel Middle primarily implemented instructional management strategies to improve student learning. One important strategy was a weekly "RTI day" in which math teachers implemented interventions for different groups of students based on district benchmark results. Similar to other schools that primarily implemented instructional management strategies, struggling students at Laurel also took an additional math class that focused on basic skills. The principal and assistant principal also reported that the math coaches planned and conducted school-level professional development for teachers; however, there was no indication in either principals' or teachers' interviews that this training had the potential to support the development of inquiry-oriented mathematics instruction.

Perspectives on Improvement. All four school leaders discussed coordinating multiple instructional management strategies to improve student performance on procedurally-oriented high-stakes assessments. Similar to principals with Function VHQMI who implemented instructional management strategies, all four school leaders discussed the importance of identifying low-performing students and placing these students in a second math class or providing targeted tutoring that focused on basic skills. Also, three of the four school leaders (Sarah, Barry, Kendra) primarily used teacher collaborative time to identify struggling students and plan interventions, such as reteaching particular standards. Two principals also discussed the importance of using intervention systems (e.g. RTI) to provide tiers of supports for struggling students. These intervention systems function to identify which students needed additional instruction on basic skills.

Professional Background and Professional Development Attended. Overall, only one of the four principals with Form VHQMI who implemented Management strategies taught middle school mathematics. Kendra taught mathematics in District C several years before the district's shift to an ambitious agenda for mathematics instruction and students' learning. Without extensive support in inquiry-mathematics instruction, it is unlikely that Kendra's experience as a math teacher would have supported her instructional leadership in inquiry-oriented mathematics.

The remaining three principals had various teaching experiences, such as art and special education.

Overall, this group of principals reported few opportunities to develop an understanding of inquiry-oriented mathematics instruction in the year of interest. Three of the four school leaders reported that they had not attended any professional development sessions that focused on mathematics instruction or instructional leadership for mathematics. The fourth school leader, Kendra, reported that she attended a PD session on the upcoming scope and sequence with her math department head. It is unlikely that this professional development training enhanced her understanding of inquiry-mathematics instruction or her instructional leadership in mathematics.

Accountability Pressures. All four principals reported that district leaders primarily held them accountable for raising test scores. Although only two of the four schools performed significantly below their respective district averages, two school leaders specifically mentioned the importance of meeting NCLB proficiency targets for specific sub-populations, particularly African-American students.

Student Demographics. Student demographics in two of the four schools influenced school leaders' expectations and professional development for teachers. In Park Falls, Sarah responded to pressures to improve performance for low-achieving African-American students by providing tutoring outside of the school day and pulling these students out of extra-curricular classes for additional instruction. Barry reported that he was expected to improve performance for both ELs and African-American students, but he did not elaborate on his strategies for supporting African American students. Math teachers at Cesar Chavez attended professional development that centered on strategies for teaching vocabulary to ELs. Prior research has found that it is more effective for ELs to be supported in developing and communicating mathematical arguments than solely focusing on vocabulary development (Moschkovich 1999). It is unlikely that the PD attended by math teachers at Cesar Chavez had the potential to improve their inquiry-oriented mathematics instruction. Although goals for improving student learning for struggling groups are laudable, there was no indication that this pressure resulted in qualitatively different mathematics instruction or qualitatively different opportunities for student learning. Strategies either related to instructional management or were applicable across content areas.

Identifying and Leveraging Expertise for Supporting Teacher Learning. There were no school leaders in this group who sought out district math specialists to either support their instructional leadership in mathematics or support substantial teacher learning. Two principals (Sarah, Greg) reported that they sought out district math specialists for advice. For example, Sarah sought advice from two district math specialists to clarify which lessons could be "compacted." That is, Sarah sought out district math specialists to see if it was possible to combine multiple lessons when the content that was not assessed by state tests, thereby freeing up instructional time for content that was assessed. The second principal did not elaborate on his advice-seeking interactions. It is unlikely that these interactions improved either principals' understanding of inquiry-oriented math instruction or resulted in learning events that had the potential to support teachers in developing ambitious instructional practices.

There was evidence that only one school-based math coach had the capacity to support math teachers in developing inquiry-oriented instructional practices. The coach at Laurel in District D reported that he conducted activities with math teachers that had the potential to support math teachers' learning; however, neither the principal nor assistant principal leveraged the work of the school-based coach as a central strategy for improving student learning. This is further evidence that the principals at Laurel framed the problem of improving student learning as improving student performance on high-stakes assessments.Principals in the remaining three schools for this group reported that their coaches did not have instructional expertise, which agreed with measurements of MKT and VHQMI. Consequently, these coaches were not positioned as having relevant expertise and were also pressed to implement instructional management strategies. Importantly, there was no indication that these principals would have leveraged a math coach with expertise given that they did not seek out district math specialists to support teacher learning.

Identifying and Leveraging Teachers with Instructional Expertise. There was evidence of only limited expertise in inquiry-oriented math instruction in each of the four schools. Each school only had one teacher in the MIST sample who conducted a lesson that was rated in the top two bands of instruction (i.e. NHWD or Ambitious). Additionally, for three of the four schools, the majority of math teachers in the MIST sample had negative MKT scores relative to the national mean. Furthermore, none of the four school leaders appeared to recognize and leverage the expertise of teachers who had developed relatively sophisticated instructional practices.

Summary. One of the key findings for this group of principals is that they did not appear to recognize and leverage the expertise of coaches or of teachers who had developed accomplished instructional practices. This was in sharp contrast to principals with Form VHQMI who implemented improvement strategies. The latter group of principals all worked with school-based math coaches, district math specialists, or accomplished teachers to support teacher learning. Interestingly, accountability pressures were similar for both groups of principals; however, one group implemented improvement strategies. Thus, there was no clear evidence of a causal relationship for both VHQMI accountability demands and principals implementing instructional improvement strategies.

Similar to principals with Function VHQMI who implemented management strategies, principals with Form VHQMI who implemented management strategies had less access to math teachers with instructional expertise than principals who implemented improvement strategies. This result was statistically significant ($\chi^2(3) = 14.95$, $p < 0.05$). As described in the prior Summary section, school leaders from both Districts A and D were more likely to implement instructional improvement strategies than principals from Districts B and C. Additionally, teachers in District A and District D had greater instructional expertise than District B and District C. It is possible that principals in District A and District D had more opportunities to understand how effective inquiry-oriented mathematics instruction positively supported student learning. Principals in District B and District C, on the other hand, were less likely to observe teachers with instructional expertise and might not have positioned high-quality inquiry-oriented math instruction as an effective strategy for improving student performance on procedurally-oriented assessments.

It is also useful to compare the two groups of principals who implemented instructional management strategies despite differences in the sophistication of their VHQMI. Both sets of school leaders primarily implemented strategies that provided additional resources for struggling students to improve student performance on procedurally-oriented assessments. Furthermore, none of the eight principals discussed leveraging the expertise of either coaches or district math specialists to directly supporting teachers' learning. In sum, the four principals who had a Function VHQMI approached principal instructional leadership similar to those who had a Form VHQMI. Additionally, there were similarities in the school and district contexts in which the two groups of principals worked. Both groups of school leaders reported similar accountability pressures from district leaders, worked with teachers who had similar levels of instructional expertise and did not attend district PD that focused on instructional leadership for inquiry-oriented mathematics instruction. These findings indicate that principals need to know more than the underlying functions of inquiry-oriented math instruction to consider how to support substantial teacher learning. Importantly, principals need also understand the challenges their teachers could face in developing inquiry-oriented mathematics instruction as well as understand which instructional leaders could support teachers' learning.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Relatively little is understood about what principals need to know and do to support instructional improvement as it relates to ambitious goals for instruction in general, and mathematics in particular. It is pertinent to address this issue given that recent increases in the cognitive demand of student learning goals (e.g. CCSSM) have implications for supporting teacher learning (Cobb & Jackson 2011a; Porter et al. 2011). Thus, it is relevant to understand what roles principals can fulfill to support teachers in developing instructional practices that address ambitious student learning goals. Prior research indicates that principals need substantial support in understanding the goals of inquiry-oriented mathematics (Nelson & Sassi 2005). Additionally, it is likely that most principals can only support teacher learning indirectly (Larbi-Cherif, 2016). Against this background, I investigated relationships between principals' understanding of inquiry-oriented mathematics instruction, aspects of the school and district context, and the extent to which principals implemented strategies that had the potential to support significant teacher learning. In the sections to follow, I first discuss my findings for my two research questions. Then, I discuss the implications for principals as instructional leaders. Last, I discuss future areas of research for principal instructional leadership.

Summary of Findings for Research Question 1

For my first research question, I investigated whether a relationship existed between the depth of school leaders' understanding of inquiry-oriented mathematics instruction and their implementation of instructional improvement strategies. I conducted a series of logistic regression analyses with implementation of improvement strategies as the outcome and Function VHQMI as the focal predictor of interest. Principals' depth of understanding of inquiry-oriented mathematics instruction, operationalized as Function VHQMI, was positively related to the implementation of instructional improvement strategies; however, the relationship was not statistically significant. Importantly, district membership had a statistically significant relationship with the implementation of improvement strategies. School leaders in District A and District D were more likely to implement instructional improvement strategies. These findings further motivated my second research question in which I analyzed how aspects of the district and school context influenced principal instructional leadership.

Findings from the first research question also indicate that the kinds of problems that principals identified were aligned with the kinds of strategies they implemented. Principals who identified problems in the quality of teachers' math instruction were more likely to implement instructional improvement strategies. Similarly, if principals only identified issues that related to student performance on procedurally-oriented, high-stakes exams (e.g. need to improve the performance of students close to proficient), then they often primarily implemented instructional management strategies that focused on additional instruction on basic skills. This finding is important because it indicates that principals who implemented instructional improvement strategies viewed effective inquiry-oriented math instruction as important for improving student learning. By valuing inquiry-oriented math instruction, these principals likely understood that teachers would need extensive support in developing instructional practices that aimed at ambitious student learning goals. Leadership content knowledge entails more than understanding important aspects of instruction; it also encompasses understanding how effective instruction relates to student learning, what teachers need to learn to develop ambitious instructional practices, and who can support teachers' learning.

Summary of Findings for Research Question 2

In addressing my second research question, I investigated how aspects of the district and school context related to the implementation of instructional improvement strategies. I did a cross-case comparative analysis for four different groups of principals. Groups were formed based on whether principals implemented improvement or management strategies, and whether principals had developed a Form or Function VHQMI. I analyzed district professional development for principals, access to educators who had the capacity to support teachers' learning, access to teachers with instructional expertise, accountability pressures on high-stakes assessments, and student demographics.

District Professional Development. District professional development for principals emerged as a key factor that related to principals' implementation of instructional improvement strategies. Seven of the eight principals who implemented improvement strategies were asked about PD they attended that school year; all seven of these principals reported attending PD that had the potential to support their development as instructional leaders in mathematics. For example, three principals attended the MIST Principal PD, which supported school leaders in identifying both high-level math tasks and important classroom interactions. In contrast, only one of the eight principals who implemented management strategies reported attending district-level training related to inquiry-oriented mathematics. Overall, school leaders in both District A and District D reported attending more professional development that focused on principal instructional leadership.

It is possible that district leaders in both District A and District D more consistently coordinated expectations and supports for principals as instructional leaders in mathematics than district leaders in District B and District D. It is challenging for large school districts to develop coherent strategies given that different central office departments (e.g. Curriculum and Instruction, Leadership, Special Education, etc.) frequently pursue competing and conflicting agendas for improving teaching and learning (Cobb & Smith, 2008; Fink & Resnick, 2001). For the four school districts in the MIST study, the Leadership Departments typically pressed for instructional management strategies aimed at improving scores on procedurally-oriented tests, whereas the Curriculum and Instruction Departments typically pressed for instructional improvement strategies aimed at improving the quality of teaching and thus supporting students' attainment of ambitious learning goals. District leaders in District A and District D appear to have been more effective in aligning the work of their Curriculum and Instruction and Leadership Departments, thereby affording their Mathematics Departments unimpeded opportunities to support substantial teacher learning.

Access to Expertise for Supporting Teacher Learning. All eight of the school leaders who implemented instructional improvement strategies turned to district math specialists or to school-based math coaches who could directly support math teachers' learning. These principals reported that they often conducted joint observations with district math specialists or school-based math coaches to assess current instructional needs related to inquiry-oriented mathematics instruction and then planned learning events that addressed these needs. In contrast, only four of the eight principals who implemented instructional management strategies sought out district math specialists for support. Of those four principals, only one principal brokered a PD session that potentially related to inquiry-oriented mathematics instruction. These findings indicate that principals who implemented improvement strategies valued effective inquiry-oriented mathematics instruction and recognized district math specialists and school-based coaches as having relevant expertise that could support instructional improvement, and as a result, student learning.

Identifying and Leveraging Teachers' Instructional Expertise. Teachers' instructional expertise emerged as an additional aspect of the school and district context that potentially supported principals who implemented instructional improvement strategies. Principals who implemented improvement strategies worked with teachers who had greater levels of instructional expertise than principals who implemented management strategies. Part of this difference in instructional expertise, though, is explained by district membership as teachers in District A and District D tended to have greater instructional expertise. As a consequence, principals who implemented improvement strategies might have had opportunities to develop an understanding of inquiry-oriented mathematics instruction through observing high-quality math instruction in their schools. Additionally, principals in District A and District D also participated in more PD that addressed instructional leadership in mathematics than principals in District B and District C. In other words, these principals might have had opportunities to substantiate what they learned in PD when they observed math lessons that contrasted sharply in quality. It is also possible that these contrasts in the quality of instruction enabled principals to clarify how effective inquiry-oriented mathematics instruction can support the development of students' conceptual understanding of important mathematical ideas.

Accountability Pressures. In this analysis, I found no relationship between current student performance and the implementation of instructional management strategies, except for principals under extreme AYP pressure. The principals of the two schools that were either reconstituted or about to be reconstituted primarily implemented instructional management strategies. There was also evidence that neither of these principals leveraged the expertise of coaches and teachers in their schools. It is possible that the pressure from district leaders to turn these schools around shaped how principals framed the problem of improvement. If district leaders evaluated principals primarily on reaching AYP targets, then these two principals might have viewed instructional management strategies as a pragmatic approach for improving student performance on procedurally-oriented exams. Interestingly, one of the two principals had a Function VHQMI and reported attending PD that improved her understanding of inquiry-oriented mathematics instruction; however, there was no evidence that she implemented instructional improvement strategies. This example further indicates the importance of district leaders supporting principals in understanding the link between effective inquiry-oriented mathematics instruction and students' development of conceptual understanding of important mathematical ideas. More generally, if principals are not supported in making this link, then it is understandable that they would primarily implement instructional management strategies to improve student performance, particularly in situations in which there are severe consequences for not meeting accountability demands.

Student Demographics. In my analysis, there was also no evidence of relationships between the racial composition of the student body, percentage of EL students, or percentage of students receiving FRLs and the implementation of improvement strategies. There were a few principals who implemented instructional programs and brokered teacher professional development to support the large EL population in their schools. Teacher reports, however, indicated that these programs focused primarily on vocabulary and basic literacy, which is unlikely to directly support ELs in learning ambitious student learning goals. More research is needed to understand how school leaders' problem frames and improvement strategies are influenced by student demographics.

Implications for Principals as Instructional Leaders in Mathematics

One of the key implications from this study is that principal professional development needs to support principals in understanding both ambitious student learning goals in mathematics and how effective inquiry-oriented math instruction can support students' attainment of these goals. Principals who implemented improvement strategies turned to district specialists or school-based math coaches because they recognized their expertise and saw it as relevant to the problems as they had framed it – supporting students' conceptual understanding of important mathematical content. There was also evidence that the principals who implemented instructional improvement strategies understood some of the challenges their teachers encountered when developing instructional practices aimed at ambitious student learning goals. Recognizing expertise in supporting teachers' learning and understanding the challenges that teachers encounter extend beyond having a functional understanding of inquiry-oriented mathematics instruction. Principal PD programs that have had some success in supporting principals' development as instructional leaders have focused on developing principals' understanding of inquiry-oriented mathematics instruction, how it relates to student learning, and challenges that teachers face when developing ambitious instructional practices (Boston et al. 2016; Nelson & Sassi 2005). Findings from my dissertation suggest that these principal PD programs focused on relevant issues for supporting principals as effective instructional leaders. As will be discussed in the following section, more research is needed to understand how principals come to value effective inquiry-oriented mathematics instruction and why they would collaborate with instructional leaders who have relevant expertise.

This study also has implications for principal instructional leadership and for how principals function within districts that are aiming to improve student learning through ambitious instruction. The extent to which principals implemented improvement strategies was influenced by access to instructional leaders with expertise at both the district and school levels. Additionally, only three of the principals had the capacity to support teacher learning directly, two of whom had backgrounds as district math specialists. This finding is important given that several models of instructional improvement place principals as a central driver for instructional change (e.g. Nelson & Sassi, 2005; Quint et al., 2007). Findings from this dissertation indicate that if principals are to play a significant role in supporting instructional improvement in their buildings, then they need to work with instructional leaders who can directly support teacher learning. Key roles for principals within a coherent system of supports for teachers include building consensus with staff on goals for student learning and instruction, identifying instructional leaders with relevant expertise, communicating to teachers expectations consistent with ambitious instruction, and fostering a professional working environment that engenders trust and risk-taking as teachers endeavor to develop new instructional practices.

An additional implication of my study concerns how the routine of observation and feedback relates to instructional improvement. In many school districts, principals are expected to support instructional change through observing teachers' instruction and providing feedback. However, there is no consensus or substantial evidence on how this practice, at the scale of school districts, results in significant reorganization of teachers' instructional practices (Rigby et al. 2017; Hill & Grossman 2013). Findings from this study indicate that if principals are expected to use observation and feedback to improve instruction, then it could be important for them to conduct joint observations with district math specialists or school-based math coaches who have the expertise to assess the quality of teachers' current instructional practices. Joint observations can support principals as they learn about important aspects of inquiry-oriented math instruction in relation to student learning, identify common instructional problems that teachers encounter as they develop ambitious instructional practices, and implement strategies for supporting teachers' learning. If principals are expected to improve the quality of instruction through observation and feedback, then they also need to have access to colleagues with relevant expertise who can directly support principals' learning.

Future Research

Findings from my dissertation indicate that more research is needed to understand how principals can be supported to understand the potential benefits of inquiry-oriented mathematics instruction and consequently recognize the expertise of staff who can directly support teacher learning. Some of the principals in this study discussed the benefits of effective inquiry-oriented instruction and the challenges teachers faced in developing ambitious instructional practices. However, it was still unclear how they had developed this appreciation and why they turned to instructional leaders who could directly support teacher learning. As mentioned in the previous section, researchers have developed PD that can support principals in understanding key aspects of inquiry-oriented mathematics instruction. However, it is less clear how principals problematize aspects of teachers' instruction and strategize how to support teacher learning. Design research on supporting the development of effective principal instructional leadership could investigate what it takes to support principals in understanding how effective inquiry-oriented math instruction can support student learning, common issues that teachers face when developing these instructional practices, and how to support principals in identifying and collaborating with instructional leaders with relevant expertise. Broadly, additional research is required to understand how to support principals' development as instructional leaders.

Common frameworks used for examining instructional leadership (e.g. sensemaking, distributed leadership) often do not take account how goals for student learning have implications for teacher learning, which also have implications for principal learning. Frameworks for distributed leadership emphasize that leadership is constituted through ongoing interactions embedded in school contexts (Spillane et al. 2004). These studies illustrate how leadership is enacted, but often do not problematize the learning demands placed on principals and teachers. Also, sensemaking research can illustrate how educators come to understand policy messages, how sensemaking is a social process, how policies are adapted as they are implemented, and how those in formal leadership positions can influence others' sensemaking (Coburn 2001; Coburn 2006). Once again, though, what principals need to learn and how they can be supported in developing the intended practices are not typically addressed in principal instructional leadership research. Research from a learning design perspective can bring into explicit focus goals for principal instructional leadership as well as designs for supporting the learning of principals (Cobb & Jackson 2012).

Further research is also needed to understand how principals problematize current instruction and student learning. School leaders who implemented improvement strategies recognized and leveraged relevant expertise; however, interview protocols did not include probes on why principals identified certain instructional issues and what challenges they anticipated in supporting teacher learning. Furthermore, interviewers rarely probed on how they identified issues and how they thought about teacher learning. Future studies can design research tools that focus on how principals problematize teacher learning and implement strategies to support teacher learning.

Finally, additional research is needed to clarify further how learning events brokered by principals can support teacher learning. I was unable to analyze learning events brokered for teachers for in analysis given the nature of data for this study, which limited my understanding of what teachers learned as a result of participating in these events. More research is needed to understand how the implementation of improvement strategies relates to teacher learning and instructional improvement. Additional research could identify the nature of teacher' learning opportunities, conditions that support instructional improvement, how principals participated in these events, and challenges that principals and coaches face when supporting teacher learning in their schools.

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Appendix A: Main Section of Principal Interview Protocol

Introductory Questions

Note to Interviewer: Only ask #1b to principals who are new to our study.

1. How long have you been a principal?
    a. How long have you been a principal at this school?
    b. What grade levels and/or subjects did you teach before becoming an administrator?

General Information about the Organization of Mathematics Teaching

I'd like to ask you a few questions about how mathematics classes are organized in your school. If the principal is a returning participant in the study, say the following: *We realize we asked these questions last year. We are checking to see if there have been any changes from last year to this year.*

2. What courses does your school offer in math grades 6-8?
    a. Do some children receive math twice a day ("double dose")
        1. *If so,* what are your goals for having children take math twice a day?

3. Does your school group children by skill level in mathematics?
    a. *If so*, what are the criteria by which you group?
    b. Are students grouped similarly for reading and math?
    c. What textbooks do the various groups use?
    d. How do you make decisions about how to assign math teachers to different skill level classes?

Goals for Math Instruction, Vision of High-Quality Math Instruction, and Assessment of Math Teachers

Now I'm going to ask you a few questions about goals for math instruction in your school.

4. How would you describe the District's vision of high-quality instruction in middle school mathematics?

5. What do you see as the district's main strategies for achieving that vision across middle school mathematics classrooms?

6. What are *your* strategies this year for improving mathematics instruction at your school?

7. What are some of the major challenges you face when working to improve mathematics teaching and learning? (*Probe on any responses that relate to hypotheses—e.g., Why do you think students are not prepared well?*)

   Anticipated responses:

   1. Lack of resources

   2. Large class sizes

   3. Unprepared students, low skill levels

   4. Teacher knowledge

   5. Resistant teachers

   6. Testing pressures

Appendix B VHQMI Interview Questions and Rubrics

Interview Questions:

“If you were asked to observe a teacher's math classroom for one or more lessons, what would you look for to decide whether the mathematics instruction is high quality?”

> “Why do you think it is important to use/do _____ in a math classroom? Is there anything else you would look for? If so, what? Why?”

For each of these three topics, the participants did not identify spontaneously, we prompted by asking, respectively,

1) What are some of the things that the teacher should actually be doing in the classroom for instruction to be of high quality?

2) What type of tasks do you think the teacher should be using for instruction to be of high quality?

3) Can you please describe what classroom discussion would look and sound like if instruction was of high quality?

VHQMI Rubric Categories include:

Role of the Teacher

Classroom Discourse (including: Patterns and Structure of Classroom Talk, Nature of Talk, Student Questions, Teacher Questions, Student Explanations)

Mathematical Tasks

Nature of Classroom Activity

Refer to Munter (2015) for a more thick description of the rubrics

Level	Description	Potential ways of characterizing teacher's role
4) Teacher as 'more knowledgeable other'	Describes the role of the teacher as *proactively* supporting students' learning through co-participation. Stresses the importance of designing learning environments that support problematizing mathematical ideas, giving students mathematical authority, holding students accountable to others and to shared disciplinary norms, and providing students with relevant resources (Engle & Conant, 2002).	*Influencing classroom discourse*: Suggests that the teacher should purposefully intervene in classroom discussions to elicit & scaffold students' ideas, create a shared context, and maintain continuity over time (Staples, 2007).
		Attribution of mathematical authority: Suggests that the teacher should support students in sharing in authority (Lampert, 1990), problematizing content (Hiebert et al., 1996), working toward a shared goal (Hiebert et al, 1997), and ensuring that the responsibility for determining the validity of ideas resides with the classroom community (Simon, 1994).
		Conception of typical activity structure: Promotes a 'launch-explore-summarize' lesson (Lappan et al., 1998), in which a) the teacher poses a problem and ensures that all students understand the context and expectations (Jackson et al., in press), b) students develop strategies and solutions (typically in collaboration with each other), and c) through reflection and sharing, the teacher and students work together to explicate the mathematical concepts underlying the lesson's problem (Stigler & Hiebert, 1999).
3) Teacher as 'facilitator'	Focuses on the forms of "reform instruction" without a strong conception of the accompanying functions that underlie those forms: either (a) views the teacher's role as *passive*, as students discover new mathematical insights as the result of collaborative problem solving (e.g. "romantic constructivism"), or (b) describes a transitional view that incorporates both teacher demonstration or introduction (e.g., at the beginning of the lesson) and 'turning it over' to the students (who then make the remaining 'discoveries'). Description likely stresses 'rules' for structuring lessons, discussion, etc. or describes posing problems and asking students to describe their strategies but does not detail a proactive role in supporting students in engaging in genuine mathematical inquiry (Kazemi & Stipek, 2001).	*Influencing classroom discourse*: Describes the teacher facilitating student-to-student talk, but primarily in terms of students taking turns sharing their solutions; Hesitates to 'tell' too much for fear of interrupting the 'discovery' process (Lobato et al, 2005).
		Attribution of mathematical authority: Supports a 'no-tell policy': Stresses that students should figure things out for themselves and play a role in 'teaching.' Suggests that if students are pursuing an unfruitful path of inquiry or an inaccurate line of reasoning, the teacher should pose a question to help them find their mistake, but the reason for doing so focuses more on not telling than helping students develop mathematical authority. Is open to students developing their own mathematical problems, but these inquiries are not candidates for paths of classroom mathematical investigation.
		Conception of typical activity structure: Promotes a 'launch-explore-summarize' lesson (Lappan et al., 1998), in which a) the teacher poses a problem and possibly completes the first step or two with the class or demonstrates how to solve similar problems, b) students work (likely in groups) to complete the task(s), and c) students take turns sharing their solutions and strategies and/or the teacher clarifies the primary mathematical concept of the day (i.e., how they 'should have' solve the task).

Figure B1. Abbreviated VHQMI Rubric: Role of the Teacher (continued on next page)

2) Teacher as 'monitor'	Describes the teacher as the primary source of knowledge, but stresses the importance of providing time for students to work together, to try on their own and make sense of what the teacher has demonstrated, to (first) explain things to each other, and then get help from the teacher.	*Influencing classroom discourse*: Suggests the teacher should promote student-student discussion in group work.
		Attribution of mathematical authority: Suggests a view of teacher as an "adjudicator of correctness" (Hiebert et al, 1997). Students may participate in 'teaching' but only as mediators of the teacher's instruction, adding clarification, etc. If students are pursuing an unfruitful path of inquiry or an inaccurate line of reasoning, the teacher stops them and sets them on a 'better' path.
		Conception of typical activity structure: Promotes a two phase, 'acquisition and application' lesson (Stigler & Hiebert, 1999), in which a) the teacher demonstrates or leads a discussion on how to solve a type of problem, and then b) students are expected to work together (or "teach each other") to use what has just been demonstrated to solve similar problems, while the teacher circulates throughout the classroom, providing assistance when needed.
1) Teacher as 'deliverer of knowledge'	Describes the teacher as the primary source of knowledge, focusing primarily on mathematical correctness and thoroughness of explanations (i.e., showing all steps). Description suggests that students are *welcome* to ask questions, but that there is no expectation that the teacher will facilitate student collaboration or discussion.	*Influencing classroom discourse*: Focuses exclusively on T→S discourse. Considers quality of teacher's explanations in terms of clarity and mathematical correctness.
		Attribution of mathematical authority: Suggests that the responsibility for determining the validity of ideas resides with the teacher or is ascribed to the textbook (Simon, 1994). (This includes insistence that teachers be mathematically knowledgeable and correct.)
		Conception of typical activity structure: Promotes efficiently structured lessons (in terms of coverage) in which the teacher directly teaches how to solve problems. Periods might include time for practice while teacher checks students' work and answers questions, but this is likely quiet & individually-based with no opportunity for whole-class discussion. Description suggests no qualms with exclusive lecture format.
0) Teacher as 'motivator'	Suggests that the teacher must first and foremost be sufficiently captivating to attract and hold students' attention.	

Figure B2. Abbreviated VHQMI Rubric: Role of the Teacher

Level	Patterns/structure of Classroom Talk	Nature of Classroom Talk	Student Questions	Teacher Questions	Student Explanation
	Description	**Description**	**Description**	**Description**	**Description**
4	Promotes whole-class conversations, including student-to-student **talk that is student-initiated**, not dependent on the teacher (Hufferd-Ackles, Fuson, & Sherin, 2004); Promotes developing & supporting a "mathematical discourse community" (Lampert, 1990),	Suggests that classroom talk should be conceptually oriented—including articulating/refining conjectures and arguments for explaining mathematical phenomena—for the purpose of supporting students in 'doing mathematics' and/or spawning new investigations.	Values student questions that drive instruction, leading to new mathematical investigations, questions characteristic of 'doing mathematics' (e.g., generalization).	Describes the role of teacher questions that are conceptually oriented ('why' questions) in driving investigations, helping students explain their problem-solving strategies, and/or helping the teacher understand students' thinking (Borko, 2004)	Student explanations include both explanation and justification (Kazemi & Stipek, 2001) with little prompting from the teacher (Hufferd-Ackles, Fuson, & Sherin, 2004)
3	Promotes whole-class conversations (about ideas, not just whole-class lecture or task set-up), but description places the **teacher at the center of talk**, likely doing most of the prompting and pressing, or calling upon students/groups to take turns presenting their strategies.	Insists that the content of classroom talk be about mathematics (e.g., asking questions, providing explanations), but description of such talk either (a) characterizes talk that is of a calculational orientation; or (b) fails to specify expectations for the nature/quality of the questions, explanations, etc.	Values student questions in the math classroom, but description suggests that procedurally-oriented questions are adequate; possibly considers the occurrence of student questions primarily among groups of students (and not during whole-class instruction).	Either (a) stresses the importance of asking conceptually-oriented questions (and details such questions with more than 'catch-phrases' such as or 'higher-order') but does not elaborate on the function of such questions in progressing classroom discourse or understanding student thinking, or (b) suggests that the teacher's questions can serve such functions but describes questions of a calculational orientation ('how' questions)—which would not actually achieve the intended function.	Description suggests an emphasis on student explanations of strategies that have primarily a calculational (rather than conceptual) orientation (Thompson et al, 1994; Kazemi & Stipek, 2001) or are not characterized
2	Values student-student discourse but describes it exclusively in the context of **small group/partner work** (if there's mention of whole-class discussion, it's characterized only as an option, not a vital element)	Insists that the content of students' classroom talk (with each other) be about mathematics, but provides no description of content (i.e., does not specify things such as questions and explanations).	Emphasizes the *presence* of student questions in the math classroom; may consider students' questions as differentiable in quality, but provides no specific criteria	Names the quality of teacher questions as an important criterion, but either (a) provides no criteria for differentiating in quality, (b) uses only 'catch-phrases' (e.g., 'higher-order', 'extension') to describe the quality of questions, or (c) examples include probing for steps taken or questioning to determine whether (but not how) a student understands ('what/how' questions, but not 'why' questions).	
1	Describes traditional **lecturing and/or IRE** (Mehan, 1979), or IRF (Sinclair & Coulthard, 1975) dialogue patterns. (Note that this can occur in a 'whole-class' setting, but is not considered a genuine whole-class discussion.)		Does not value student questions, or suggests that students should be welcome to ask questions, but that the presence of student questions is not inherently a good aspect of classroom discourse.	Names the presence or quantity of teacher's questions as an important criterion, or describes a scenario where students offer one-word or short-phrase answers to questions the teacher asks as (s)he demonstrates, or suggests that the role of teacher's questions is to keep students on task.	

Figure B3. Abbreviated VHQMI Rubric: Classroom Discourse

Level
4) Emphasizes tasks that have the potential to engage students in "doing mathematics" (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998), allowing for "insights into the structure of mathematics" & "strategies or methods for solving problems" (Hiebert et al, 1997).
3) Emphasizes tasks that have the potential to engage students in complex thinking, including tasks that that allow multiple solution paths or provide opportunities for students to create meaning for mathematical concepts, procedures, and/or relationships. "Application" is characterized in terms of problem-solving. However, tasks described lack complexity, do not press for generalizations, do not emphasize making connections between strategies or representations, or require little explanation (Boston & Wolf, 2006). Instead, they emphasize connections to "the real world, or "prior knowledge." Reasons for multiple strategies are not tied to rich discussion or making connections between ideas.
2) Promotes 'reform'-oriented aspects of tasks without specifying the nature of tasks beyond broad characterizations (e.g., "hands-on," "real world connections," "higher order"), and without elaborating on their function in terms of providing opportunities for "doing mathematics" (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998). "Application" is characterized in terms of "real world" *context* and/or students being active.
1) Emphasizes tasks that provide students with opportunity to practice a procedure before then applying it conceptually to a problem (Hiebert et al, 1997)
0) (a) Does not view tasks as inherently higher- or lower-quality; or (b) Does not view tasks as a manipulable feature of classroom instruction

Figure B4. Abbreviated VHQMI Rubric: Mathematical Tasks

Level	Description
2) Specifies WHAT Ss should be doing using typical reform language, without describing the nature of classroom activity in content-specific ways--focuses primarily on the organization/structure of the activity (form view).	Describes what students should be doing without mention of the content of their interactions (i.e., describes a 'non-traditional' classroom, full of activity, but does not specify how the activity is specific to mathematics). If reasons WHY particular forms of activity are important are provided they are not in terms of supporting students' participation in doing mathematics.

1) Stresses the importance of students being engaged and "on-task", either taking for granted the *quality* of classroom activity (i.e., students should be doing whatever the teacher asked), or specifying traditional classroom activities as what should take place.	(a) Stresses THAT students should be engaged and participating in classroom activities (i.e., on-task, paying attention), without specifying WHAT those activities should be; OR, (b) Describes nature of classroom activity as traditional classroom activity.

Figure B5. Abbreviated VHQMI Rubric: Nature of Classroom Activity

Appendix C: Example of School-Year Memo

School-Year	Notes on Context	Methodological Notes	Problem: Diagnostic	District Vision	Principal Strategies	Analytical Notes	Diagnostic Framing	Orientation
A2_2Steve, Year 3	principal understands that district A is aiming for ambitious instructional goals, understands that it requires time to develop teachers,	Interview is all over the place and does not follow protocol, difficult to code,	Not asked	students construct mathematical knowledge rather than being told by a lecturer, students are pressed for explanations, Teachers are to press students for different solutions,	Additional CMP2 instruction for students who need more help with getting homework started -- additional instructional time to support deeper understanding of content. Principal understands that Inquiry instruction takes a long time to develop and that this is a multi-year process.	Code for instructional improvement/management because principal understands that both students and teachers need additional time for ambitious math instruction; states perspectives on teacher learning and ideally values professional development that supports teacher learning from expertise. Understands that CMP2 instruction requires deeper knowledge -- knowledge that is beyond generalists or elementary teachers	No code	Instructional Improvement

Appendix D: Type of Lesson as Categorized by IQA

- *Traditional*: the teacher does not select conceptually rigorous task, instead presents a task that emphasizes the application of a procedure to produce a correct answer without making connections to deeper mathematical concepts or meaning.
- *Proceduralized*: the teacher selects a cognitively demanding task with multiple solution methods, but then transforms the task into a procedural activity, thereby lowering the cognitive demand and restricting the number of potential solutions.
- *Low-level discussion*: the teacher selects a cognitively demanding math task and allows the students to explore the mathematical concepts. However, the teacher does not lead a concluding whole class discussion in which students are pressed to explain their reasoning and connect their solutions to different solution methods. This includes students describing their solutions without describing why their solutions are valid.
- *Ambitious:* the teacher selects a cognitively demanding task, allows the students to explore the mathematical concepts, and leads a whole class discussion in which students are pressed to explain their reasoning and connect different solutions. Although some phases of the lesson may not be exemplary, there are opportunities for rigorous student

Appendix E: School Context Memo Example

Category	Data	Analytical notes
Professional background	Notes on school leader's professional background. Make notes of experience and any other aspects of work history that could have influenced how school leaders think about inquiry math. (Source: SSF, Principal ISF, and Interview).	School leader hired current district math coach five years ago. Interactions influenced how school leader thinks about math instruction and how school leader thinks about influencing student learning. – Support for school leader learning.
School Background	Record notes on school context to understand if there are key aspects of the school. (Source: SSF)	School has several district coaches, including one for math, because of persistent low achievement. As a result, the school leader is not involved in math instruction.
Student Demographics	Record notes on the percentage of students who are African-American, Latino/Latina, African American, FRL, and EL. (Source: MIST Databases)	The school had a large percentage of students who are learning English, and this influences how school leader problematizes student learning in mathematics. Works literacy into all classrooms.
Student Performance	Record notes on rates of student proficiency for each grade level for both the school and district. Also, when available, record notes on whether or not the school met AYP in general and for math, and the AYP Stage (Source: MIST Databases).	The school is below district average by at least 10% for each grade level. The school is also Stage 5 AYP. Likely that school leader is under pressure to raise student performance.
Accountability Pressures	Record notes from school leaders' interviews on school leader reports of accountability pressures. (Source: principal interview, principal ISF, SSF).	Principal reports that all they are held accountable for is raising test scores. Evidence that this could influence how school leaders frame the problem of improving mathematics instruction.
School Leader Professional Development	Record notes on the professional development that the school leader has participated in for that school year. (Source: principal interview, principal ISF, SSF)	School leader reports that he has not participated in any professional development this year that addresses instructional leadership in mathematics – only PD for science. Unlikely that PD will support principal in developing a functional

		understanding of inquiry math instruction.
Evidence of Instructional Expertise	Record notes on VHQMI, MKT, IQA, and IQA lesson category for all full participants (school leaders, coaches, teachers) within the school. (Source: SSF, principal interview, principal ISF, MIST Databases).	There is little to no evidence of expertise within the building. All teachers were categorized as having proceduralized or traditional lessons. All teachers and math coach have MKT scores that are less than 1 SD above the mean. Three of the five teachers have an MKT that is 1 SD below the mean. No evidence that members within the school building have a functional VHQMI. School leader turns to school-based math coach for advice; however, the main focus of conversations is to identify students for additional tutoring based on student performance on district benchmarks.
Identifying and Leveraging Expertise for Supporting Teacher Learning	Record notes on who the principal turns to for advice on math instruction. (Source: principal interview, principal ISF, SSF).	School leader does not seek out advice from district math coaches. School leader did not report that they worked with external consultants on issues relating to mathematics instruction.
Problems and Strategies for improving student learning and inquiry math instruction	Record notes on problem statements and strategies that pertain to math instruction. (Source: principal interview, principal ISF, SSF).	School leader presses teachers to work on data analysis and reteaching when they collaborate. Teacher reports of collaboration activities generally agree with principal expectations. Focus of teacher collaboration is on instructional management
Methodological Issues	Record notes on missing data or other issues that might limit addressing research question 2. (Source: principal interview, principal ISF, SSF).	School leader was not asked the network questions on whom they turn to for advice on mathematics instruction. Potential for important missing data.

Summary of Key Findings	Summarize key findings here from above categories. Use this for analysis and when making each Quadrant memo.	Overall, no evidence of instructional improvement strategies. The focus of teacher collaboration is on identifying struggling students and reteaching content. No evidence of expertise within the building. Principal and coach work together, but primarily to target students for additional tutoring.

Appendix F: Conjectures on relationships between context and principals' strategies

Aspects of School and District Context:	Conjectures
Organization of Teaching	School size can influence coherency of an instructional vision and access to expertise. Schools with more teachers are more likely to have expertise; however, it might be more difficult to form a coherent instructional vision with more teachers. Schools with a relatively small math department might have less access to expertise, but might be able to more easily form consensus around goals. If teachers do not regularly collaborate to analyze instruction and its influence on student learning, then it is more likely that instructional leadership will be diffuse and not provide strong guidance.
District Leader Expectations:	District Leader expectations can significantly influence principals' perspectives as instructional leaders (Honig, 2012) given that district leaders evaluate principals' performance, have positional authority, and can coordinate support for principals from the district office and other regional bodies. If leadership directors can distinguish between low- and high-quality forms of inquiry-oriented instruction, then they are more likely to support and hold school leaders' accountable for making similar distinctions. (MIST)
Accountability Pressures	Principals in schools that are under intense pressure to improve test scores (e.g. under threat of reconstitution) might be more likely to implement instructional management strategies given that these strategies could be viewed as pragmatic and effective for improving student achievement on procedurally-oriented state assessments. If a struggling school has regular collaboration with leaders at various levels (e.g. district, state), then it is likely that they will implement instructional management strategies to effectively communicate with various stakeholders who likely have different views on what counts as quality mathematics instruction. Prior student achievement status might influence principal, coach, and teachers' sense of efficacy, collective efficacy, and views of students' mathematical capabilities (i.e., it might be harder for staff in a chronically low-achieving school to consider ambitious math instruction as feasible). (MIST)
Access to Expertise for Supporting Teacher Learning	Coaches who have more instructional expertise than teachers can potentially support teacher learning directly. They might also have the capacity to support principals' understanding of mathematics instruction through ongoing interactions that focus on instruction.

	This could then increase the likelihood that principals and coaches identify relevant problems in current instruction and develop instructional improvement strategies.
Identifying and Leveraging Teachers' Instructional Expertise	Principals' capacity to distinguish between high and low enactments of inquiry-oriented math instruction can depend on the contrast of instructional quality present in their schools. Principals who have opportunities to observe high-quality enactments of inquiry-math instruction are more likely to understand how such instruction can influence student learning, which in turn can influence them to position effective inquiry math instruction as a key strategy for substantially improving student learning.
Student Demographics	School leaders with a greater proportion of students who are FRL, ELs, and SPED are more likely to implement additional tutoring programs and other support services (e.g. ELL education, second math classes, bus transportation, support staff) to support the work of mainstream instruction (MIST).

Appendix G: Quadrant Memo

Category	Petra Y4	Tom and Albert Y3	Tamara Y4	Connie Y4
Professional background	• 1st year in SUN RIVER; P & AP in 6th-grade school for eight years prior. Attended CMP2 PD in Michigan some years back as an assistant principal • Interesting, she seeks out the math specialists. Used to work with B_1Kandi at the 6th-grade middle school.	• Albert is in charge of the math department and has experience teaching HS math. Also, has a Bachelor's In Math.	• 3rd year as P in Birch. Tamara was an AP for six years before becoming a principal. Taught science before becoming an administrator • Principal worked with resource teacher another school. Given this history, Tamara worked with district leaders to ensure that this resource teacher was assigned to her school	• HS Social Studies Teacher for five years before becoming a Principal • Three years as P in school
School Background	• The math department is split along grade level teams (7th and 8th) with few reported interactions relating to instruction across grade levels.	• Math/Science/Technology Magnet. Students in Advanced classes also take supplemental extension classes to support student learning.	•	• Connie reports that this school has the most NCLB targets (22) in the state. • Also, due to low performance in another middle school, many EL students were placed in Magnolia. The school was not provided with additional resources to teach the new students

Student Demographics	• SUN RIVER has more students who receive FRL (83% to 76%), less ELs (13% to 28%), and more African American students (34% to 23%). • SUN RIVER also has less White Students (3% to 14%) than the district average.	• Missing data for FRL and EL. Otherwise, student demographics are very comparable to district averages.	• FRL and ELL numbers are missing for this school. • 95% of the students are white in this school, which is much greater than the district average of 53%	• Magnolia has more minority students than the district average. Missing data for FRL and EL
Student Performance	• SUN RIVER performed below the district average and failed to meet AYP in Y3. • The school is Stage 4, which indicates that this school might be under pressure to raise test scores	• School CYPRESS performs better than the district average; however, did not make AYP. Unsure if this school is under pressure to raise test scores.	• Birch performs significantly below the district average. Likely to be under a lot of pressure given that the school is Stage 5, Y4 – indicating that it has almost been a decade since the school made AYP targets	• Magnolia performs below the district average in all grades. The school is in NCLB Stage 5.5 and is likely to be under pressure from district leaders to improve test scores.

Accountability Pressures	• Overall, Petra reports that she is held accountable for raising test scores. Also joked around with being fired if she doesn't raise test scores.	• Both the AP and P report expectations that align with being in the classroom. The AP reported that he is expected to have a productive relationship with both the school and the district coach and to bring in "high quality" PD.	• Tamara reports that she is under pressure from district leaders to improve test scores	• Expectations to raise test scores from a principal supervisor. School is Stage 5 AYP and a priority school
Professional Development	• Attended CMP2 PD in years prior as an AP, which helped her understand CMP2. This year, Petra attended one session that focused on comparing student work across campuses. She found this helpful, but this was not probed.	• Tom attended the MIST Principal PD. He found t very helpful as it helped him to know what to look for when observing teachers. • Albert reported that the MIST Principal PD. was not helpful because he felt like it didn't teach him something new. Reports that it could have been useful for others who don't have same math background	• Attended MIST Principal PD in Y3. Found it helpful to understand what to look for when observing instruction and what to press teachers on when giving feedback to teachers.	• Not asked in Year 4. Attended MIST Principal PD in Y3. Commented on how helpful this PD was in Y4.
Identifying and Leveraging	• Petra has discussions with the coach about how to support teachers. In joint	• Albert is in charge of math. • The math coach presses and supports teachers in	• Meets with district coach to understand which teachers	• Tension between coach and teachers. Principal values the expertise of a particular

Expertise for Supporting Teacher Learning	consultation, brought in a consultant to do a session on CMP2. PD focused on planning CMP2 investigations at adequate depth and forming questions to press student thinking • Petra seeks out B_1Kandi – district math specialist to observe teachers, give feedback, and provide recommendations on how to support the math department. • The district math specialist observed teachers, gave feedback, and recommendations for how to support that teacher (e.g. coaching, pull-out PD)	improving instruction. Meets with teachers to give feedback, also communicates Ps and APs expectations to teachers. Coach focuses on instruction and making sure it is "high quality." • Math coach also modeled lessons for teachers. • Albert expects for all teachers to work with math coach – instructional expectations and supports the work of the coach – important	are struggling – potentially productive strategy • In-house resource teacher helps compile data reports for all teachers – this RT is a content-general specialist. • Tamara will seek out advice from Barbara on what she observes in the classroom and how to help math teachers improve.	teacher and encourages teachers to go seek out expert teacher rather than the coach. This advice is supported by MIST measures of expertise – teacher has expertise rather than coach. Principal demonstrates capacity to identify high-quality enactments of inquiry-math instruction
Teachers' Instructional Expertise	• Overall there isn't evidence of expertise within the school. The coach has a functional VHQMI, and one teacher has an MKT 1SD above mean. • All four teachers were categorized as having proceduralized lessons.	• Three of five teachers have lessons in top two bands. Math teacher with Amb lesson ends up becoming a math coach later in the study. • Susan has the most sophisticated vision and highest MKT score; however, chose a low-level task for video recording • District Coach appears to have expertise as the district coach – Functional	• Evidence of some expertise within the school as 2 of 4 teachers had lessons in top two bands, with one of them ambitious. Other two teachers were classified as proceduralized • Kacey is potentially an expert, MKT 1SD above mean – Functional VHQMI.	• Evidence that the coach has expertise (MKT VHQMI) – however, this coach works primarily with the data and not with math teachers. • There is evidence that three of the five teachers have instructional expertise. However, all give teachers have negative MKT scores with two of them at least 1SD below the mean • Evidence that principal has identified the teacher with

		VHQMI and high MKT (~1 SD above mean)		the most expertise. P also encourages teachers to work with and observe her classroom.
Perspectives, problems, and solutions relating to student learning	• Petra prioritizes student performance – in a sense, the ends justifies the means. Teachers are given autonomy on instructional decisions as long as this is backed up by student performance data	• Students can get out of additional math class if get up to grade level marks on computer software program. School is making Robotics class as an incentive to get out of double dose	• Additional math class for struggling students to support students in inquiry-math class	• Struggling students receive math twice a day to build up basic skills
Perspectives, problems, and solutions relating to teacher learning	• TCT meetings focus on data analysis for reteaching. Strong instructional management approach. • Observations and feedback unlikely to support teacher learning – focus on student engagement, hands-on activities, and students collaborating – form view • Petra noticed a direct instruction problem and brought in PD on cooperative group work – which isn't necessarily an instructional improvement strategy	• Grade level planning is the main form of teacher collaboration. 8th-grade team has potentially productive meetings – looking at student work, discussing when to use certain tasks • Evidence that Albert gave feedback to teachers that aligned with CMP2 and the LES format • Albert has the capacity to identify when teachers are incorrect mathematically and give feedback based on content – this is very atypical. Unsure though how it relates to inquiry-oriented math	• Monthly PD led by Kacey. Principal reports that this has focused on planning upcoming content-- unsure if this is related to instructional improvement. • Uses mission and vision statements to communicate the importance of inquiry math instruction. However, given the form understanding of this principal, the effectiveness of these expectations is highly dependent upon expertise being present within the building to elaborate on these expectations. • P acknowledges that there is an issue with low-level instruction, primarily because most of the math	• School-based PD has potential to support teacher learning: focused on Accountable Talk as well as how to teach CMP2 and how to deal with student struggles with CMP2 • Math department meets monthly, but these meetings are unlikely to support substantial teacher learning.

			teachers are new. She also hinted previously that there is trouble with teacher collaboration •	
Perspectives on improvement	• Improvement happens through identifying key instructional issues and bringing in professional development to address these issues. Some of the identified issues relate to inquiry math • Petra prioritizes student performance – in a sense, the ends justifies the means. Teachers are given autonomy on instructional decisions as long as this is backed up by student performance data • The principal has given teachers data reports that compile data on how students are performing on each assessed standard. Teachers are to use these reports to form intervention plans, identify struggling students, and reteach content.	• Coordinate expectations across multiple instructional leaders. AP, school coach, and district math coach all regularly observe teachers to press on inquiry-instruction. • Send all math teachers to CMP2 training in Michigan State to support teacher learning.	• Sent all math teachers to CMP2 training in Michigan State to support teacher learning. • Improvement happens through seeking out expertise and assessing teacher needs related to inquiry-math instruction. Tamara regularly has discussions with both the district coach and specialist to understand what supports math teachers need. For example, Tamara will seek out advice from Barbara to discuss what is going on in math instruction and how to support teacher learning. • Tamara produces performance reports that Color-codes students and communicate to	• Teachers report that they are expected to improve the quality of math instruction and to build relationships with students rather than focus solely on test results – despite low achievement and pressure from district to raise test scores. • Principal focuses on how lessons are implemented rather than just examining lesson plans to determine instructional quality. This is a shift in perspective that was facilitated by participation in the Vandy/Pitt PD

			teachers her expectations to raise test scores. Holds teachers accountable for raising test scores. Teachers have data reports on how students are performing and understand the expectations to improve student performance.	
Summary – key factors	• Coordinates with school coach, district coach, and external consultant to identify instructional issues and support teachers. E.g. noticed that teachers weren't pressing students on reasoning, brought in PD that focused on planning CMP2 investigations with adequate depth. • The absence of instructional expertise – all four teachers were categorized as having procedurarlized lessons. • Petra's vision of math is unlikely to directly support math teachers' learning – focuses on student engagement.	• Albert is in charge of the math department. He has experience teaching HS math and also has a BS in Mathematics. • Math/Science/Technology Magnet • Both principal and assistant principal report that they are not under pressure to raise test scores. Albert reported that he is expected to form relationships with both the school and district coaches to bring in "high-quality" PD • Evidence of expertise within the school: Three of five teachers have lessons in top two bands. D_3Angela also has a functional vision and a very high MKT	• Has sent Ts to CMP2 PD over 1st two years to support teacher learning. • Tamara worked with Kacey as a teacher and brought her on board when started as principal at Birch • Tamara did not demonstrate the capacity to provide feedback that can support instructional improvement. • Most of the math department have 1-2 years of teaching experience – dependent on external expertise • Principal will also seek out Barbara for clarification on how teachers are to teach CMP2 and use assessments built into the curriculum	• Connie reports that this school has the most NCLB targets (22) in the state. • Diverse group of EL Students: more than 25 languages in school • Expectations to raise test scores from a principal supervisor. School is Stage 5 AYP and a priority school • Principal demonstrates capacity to identify high-quality enactments of inquiry-math instruction • Evidence that school-based PD has potential to support teacher learning – Sessions on Accountable Talk, as well as how to teach CMP2, and how to deal with student struggles with CMP2

	• SUN RIVER was at Stage 4 in Y4. Petra reported that she is held accountable for raising test scores. • Petra prioritizes student performance. Teachers are given autonomy on instructional decisions as long as this is backed up by student performance data • Coach has difficulty accessing teachers and overall teachers report that they do not view the school coach as an instructional resource	• 8^{th}-grade team potentially has meetings that could support instructional improvement: evaluate student work to decide which tasks to use in upcoming lessons • Albert potentially has the capacity to give teachers feedback that can support instructional improvement • The principal, AP, and school coach all coordinate to communicate expectations to teachers. Coach conducts coaching cycles with teachers.	• P acknowledges that there is low-level instruction throughout the school • Principal expects to see the forms of math instruction (e.g. group work and whole-class discussions), but doesn't have a solid understanding of the functions (e.g. math is something done step-by-step)	

Appendix H: Pseudonyms by District, School, and Quadrant

District	School	Name	Role	Group
A	District Office	Tammy	District Math Specialist	
	Stewart	Sam	Principal	Function-Improvement
	M.C.Gable	Milt	Principal	Function-Improvement
	Colman Middle	Devin	Principal	Function-Management
	Widmark	Red	Principal	Function-Improvement
B	District Office	Jenni	District Math Specialist	
	Sun River	Petra	Principal	Form-Improvement
	Green Springs	Mary	Principal	Function-Management
	Two Lagoons	Vera	Assistant Principal	Function-Improvement
	Creekside	Ross	Assistant Principal	Function-Management
	Park Falls	Sarah	Principal	Form-Management
C	Baldwin MS	Bobby	Principal	Function-Management
	Cesar Chavez	Barry	Principal	Form-Management
	C. Wright Mills	Greg	Principal	Form-Management
	C. Wright Mills	Kendra	Assistant Principal	Form-Management
D	District Office	Barbara	District Math Specialist	
	District Office	Kacey	District Math Coach	
	Cypress	Tom	Principal	Form-Improvement
	Cypress	Albert	Assistant Principal	Form-Improvement
	Birch	Tamara	Principal	Form-Improvement
	Magnolia	Connie	Principal	Form-Improvement
	Laurel	Bill	Principal	Form-Management