Learning Opportunities about Teaching Mathematics: A longitudinal case study of school leaders' influence

Jessica G. Rigby
University of Washington

Christine Andrews-Larson
Florida State University

I-Chien Chen
Michigan State University

Structured Abstract

Background/Context: When new, rigorous standards are adopted, teachers often need to learn new content and new ways of teaching while concurrently attending to accountability demands. Both formal and informal school structures potentially enable this new learning, and school leaders likely influence the nature of these structures.

Purpose/Objective/Research Question/Focus of Study: We examine teachers' learning opportunities in one school by asking the following research questions:

1. What is the nature of changes in teachers' formal learning opportunities, as seen by changes in teachers' workgroup conversations about mathematics instruction?
2. In what ways do school leaders shape the nature of instructional conversations, and thus formal learning opportunities, in teacher workgroups?
3. What is the nature of changes in teachers' informal opportunities to learn, as seen by shifts in informal advice networks?

Research Design: Longitudinal case study using mixed methods: qualitative analysis of audio-recorded teacher workgroup meetings and quantitative analysis of informal social networks.

Data Collection and Analysis: This analysis is a part of a larger, eight-year longitudinal study, the Middle-school Mathematics and the Institutional Setting of Teaching (MIST). Data used in this analysis were collected over a three-year period in one middle school working to improve mathematics instruction by focusing on teaching mathematics conceptually as well as building procedural fluency. Data used in this analysis include: audio-recorded teacher workgroup meetings, informal social network surveys, interview transcripts, and student-level standardized tests scores.

Findings/Results: We found that formally, school leaders shifted teachers' workgroup conversations away from instructional matters to those of standardized tests. Informally, teachers stopped going to each other for instructional advice. Triangulating interview data confirmed that, over time, pressure teachers felt to do well on the standardized tests shifted their attention away from a conceptual

approach to instruction towards an emphasis on test-preparation.

Conclusions/Recommendations: Our findings suggest that school leaders must be involved in new learning about standards and instruction in order to appropriately support teachers' learning opportunities.

Key Words: Administrators, Informal Social Networks, Teacher Learning Opportunities, Mathematics, Accountability

Introduction

At this critical instructional policy juncture in education in the United States, school leaders face new challenges paired with new opportunities to support teachers' learning about instruction. In recent years, nearly all states adopted either the Common Core State Standards (CCSS) or similar rigorous standards that entail significant shifts in student learning. For example, the CCSS—Mathematics have an increased emphasis on conceptual understanding, flexible use of procedures, and problem-solving applications. Implementing these standards entails change in instructional practice that requires substantial learning on behalf of adults. Both teachers and those who support them often need to learn new content and pedagogy. The context of the accountability movement complicates this formidable challenge of supporting adult learning and instructional change. School districts are faced with the challenge of concomitantly building the capacity of their principals, coaches, and teachers while also meeting metrics on standardized tests. These dueling priorities do not necessarily have to be in conflict; when students gain a deep conceptual understanding of material they are able to perform well on procedural tasks (Riorden & Noyce, 2001; Tarr et al., 2008). However, there is evidence that teachers, school leaders, and district leaders sometimes view these as competing priorities (Kerr, Marsh, Ikemoto, Darilek & Barney, 2006). This is a study of teacher learning opportunities situated in an "accountability" context.

To support the slow process of sustained instructional change, teachers need ample opportunities to engage in discipline-specific learning, to receive ongoing and embedded support from an instructional leader(s), and to feel comfortable deviating from their traditional instructional practices without the risk of a negative evaluation (Borko, 2004; Bryk, Sebring, Allensworth, Luppescu, & Easton, 2010; Darling-Hammond & McLaughlin, 1995). One key lever in this learning

process is the school leader(s). This analysis examines how the leaders in one school, a principal and assistant principal, influenced teachers' learning opportunities while they engaged in the tension between learning to teach ambitious mathematics while also meeting accountability demands. Accountability pressure coupled with new academic standards is a common context in today's schools; this study is a case of school leaders' response to this challenge and its relation to teachers' opportunities to learn.

This is a longitudinal case study (Yin, 2003) of Creekside Middle School's[1] efforts to improve mathematics instruction in alignment with a district initiative for conceptual, inquiry-based instruction. The case of mathematics is useful to understand the tension between the implementation of rigorous standards in the context of accountability as the field of mathematics education has made great progress in identifying goals for students' learning and specifying forms of instructional practice that support those learning goals (Franke, Kazemi, & Battey, 2007), as well as clarifying what teachers need to learn to be able to implement such forms of instructional practice (Franke, Carpenter, Levi, & Fennema, 2001; Hill, 2010; Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010). This elaborated knowledge allows for a robust discipline-specific analysis of teachers' opportunities to learn.

In this case, the district's goal included supporting students to engage in cognitively demanding tasks (Stein & Lane, 1996) that require students to make sense of the mathematical relationships at hand (Lampert et al., 2010), or "ambitious mathematics." To support teachers' learning and change in practice, the district provided new curriculum and ongoing professional development for teachers, instructional coaches, and school leaders (principals and assistant principals). While the district sought ambitious instructional practices, the state's standardized tests required expertise in procedures and

[1] All names are pseudonyms.

fluency. These forms and evidence of knowledge are not inherently at odds, yet at the time of this study the standardized tests required a procedural-level of thinking (Stein, Grover, & Henningsen, 1996; Thompson, Philipp, Thompson, & Boyd, 1994).

In an effort to capture the broad range of ways in which teachers learn, we examined both formal and informal opportunities at Creekside, and the school leaders' influence on these opportunities. This is a unique approach: many studies consider formal learning opportunities such as professional development sessions, teacher workgroup conversations and activities, or classroom observations and feedback routines, or consider informal learning opportunities such as social networks to assess teachers' access to information. Our unique data set provides the ability to examine both types of learning opportunities over a three-year period, allowing us to explore the relationship between informal and formal opportunities. This novel approach provides the field with a more robust understanding of how schools engage in learning as a key facet of organizational change in the context of seemingly competing demands of accountability and ambitious instructional improvement, and the role school leaders play in shaping this engagement. We found, over the three years, an increased active presence of school leaders in the teacher workgroups that shifted teachers' conversations away from instruction and towards standardized testing, and a splintering of the informal advice network. Taken together, our analyses suggest that school leaders can influence both the quantity and quality of teacher learning opportunities that have the potential to support teachers' development of ambitious instructional practices.

Review of Relevant Literature

One approach to building teacher capacity is through the attention to relationships: among teachers, as well as between teachers and others such as coaches and school leaders. Information and

resources (e.g., access to expertise with regard to mathematics instruction) are embedded in social structures and relationships; this type of resource is operationalized as social capital (Bourdieu, 1985; Coleman, 1988; Putnam, 1993). Social capital theory argues that individuals have different access to resources depending on the nature of their relationships.

Providing structured time for teachers to meet and discuss their practice is one formal way to increase teacher interactions, and thereby share social capital. Researchers have examined formal learning opportunities as they are situated in *teacher workgroups* more broadly (Borko, 2004; Horn, Kane, & Wilson, 2015; Kazemi & Franke, 2004). Teacher workgroups offer opportunities for teachers to deprivatize their practice, discuss student learning, collaborate around instruction, and develop shared language, among other interactions that may lead to productive changes in instructional practice (Grossman, Wineburg, & Woolworth, 2001; Huggins, Scheurich, & Morgan, 2011). While some researchers point out that teacher workgroups frequently exist and meet without these benefits, the potential for radical instructional change exists with appropriate supports, particularly in the form of content-specific instructional expertise and leadership (Horn et al., 2015; Van Lare & Brazer, 2013). Current research suggests that formal teacher learning opportunities are either supported or hindered by the content of the meetings, group dynamics, and access to expertise (Horn & Kane, 2015; Stein & Coburn, 2008). We are interested in how school leaders productively engender teacher learning and strong collaborative relationships in such contexts.

The Role of School Leaders in Formal Teacher Workgroups

The research on the role and influence of school leaders on teachers' collective learning opportunities include structural strategies such as setting aside time for teachers to meet (Fleming, 2004; Huffman, Hipp, Pankake, & Moller, 2014), including teachers in decision-making processes

(Morrissey & Cowan, 2004), providing resources such as substitutes and instructional materials (Rigby, Forman, & Lewis, 2019; Huffman, et al., 2014), and monitoring the work of the workgroups (Murphy, 2015). More adaptive strategies focus on school leaders' actions to foster conditions under which teachers are able and willing to take risks to learn and change their practice. These include: creating a culture that enhances learning (Schein, 1985), supporting and legitimating reflection and collaboration (Shulman, 1997), focusing attention on student learning (Louis, Marks, & Kruse, 1996; Morrissey & Cowan, 2004), building teacher morale (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006), and building relational trust (Cranston, 2011). Huffman et al. (2014) also argue that a principal should apply pressure, provide support, and reinforce signs of growth. The notion of "pressure" is a soft nod to accountability. These findings are congruent with other literature on the mediated role of principals in improving student outcomes; school leaders can engender conditions under which teachers concurrently learn and focus on student learning (Grissom, Loeb, & Master, 2013; Sebastian & Allensworth, 2012).

Informal Social Networks and Access to Social Capital

While scholars have investigated the ways in which formal workgroups afford and constrain teachers' professional learning opportunities, others have used social network analyses to investigate similar questions, especially around informal advice seeking. A social network is represented by the mapping of actors and the connections among them. Social network scholars posit that depending on a person's location in a social network, they have access to different information and sets of ideas (Adler & Kwon, 2002; Ahuja, 2000; Penuel, Riel, Krause, & Frank, 2009; Small, 2009; Uzzi, 1996). Sun and colleagues (2014) found that teachers who sought advice from more expert peers exhibited improvement in the quality of their own instructional practices, and Coburn and colleagues (2010)

found that access to support networks in which teachers seek advice regularly from more expert others was an important support for sustaining instructional reform.

Social network analyses have also examined the role and influence of school leaders on how information and resources are accessed through networks. In a comparative case study, Penuel et al. (2009) investigated the similarities and differences between two schools participating in instructional reform and argued that the principals' distinct approaches mattered for teachers' levels of perceived trust, and subsequent willingness to take instructional risks in relation to reform. Another study found that the more central a principal was in their elementary school network the more likely their teachers were to invest in innovative practices and creation of new knowledge (Moolenaar, Daly, & Sleegers, 2010). However, other studies suggest that the relationship between formal hierarchical structures and informal social networks is not always tightly linked, as principals were on the periphery of teachers' advice networks (Berebitsky & Andrews-Larson, 2017; Moolenaar, 2012).

Both teacher workgroups and informal advice networks highlight elements of teachers' opportunities to learn, share, and influence colleagues' ideas about instruction. The social structure of schools, as seen through their networks, can either impede or provide the access to information and support needed to develop and sustain ambitious mathematical instructional practices. Network analyses allow us to see how individuals are situated in the social structure, which provides insight into their access to such information and support. Analyses of workgroup conversations allow us to identify approaches and understandings of mathematics instruction (Penuel et al., 2009). By drawing on both sources of data in concert, this case study illustrates the potential influence of school leaders on teachers' access to learning opportunities, both through the nature of their conversations in teacher workgroups and through their informal advice-seeking behavior outside of structured time for

collaboration. We examine school leaders' influence on teachers' learning opportunities through the following research questions:

1. *What is the nature of changes in teachers' formal learning opportunities, as seen by changes in teachers' workgroup conversations about mathematics instruction?*
2. *In what ways do school leaders shape the nature of instructional conversations, and thus formal learning opportunities, in teacher workgroups?*
3. *What is the nature of changes in teachers' informal opportunities to learn, as seen by shifts in informal advice networks?*

Conceptual Framework

In this paper we rely on two theories to guide our analyses, aligned with our focus on both formal and informal learning opportunities: framing and social capital theories. First, employing the concept of framing, we examine how individuals influence others' perceptions of the problem of teaching mathematics in the teacher workgroup setting. Framing theory posits that individuals actively engage in producing meaning for others (Cress & Snow, 2000). A frame can be thought of broadly as the way in which an idea is presented to an audience. The ongoing act of framing is seen as meaning construction, often contentious in that the generation of new frames may both differ from and challenge existing ones (Snow & Benford, 2000, p. 614). This is done both through diagnostic framing, or describing a problem or issue at hand, and prognostic framing, or stipulating the remedy for a problem. By strategically defining problems and proposing solutions, individuals highlight some ideas and downplay others. The way in which a problem is framed, especially by an individual (or individuals) in formal positions of power, such as a principal, legitimizes certain policy design and delegitimizes others (Coburn, 2006; Cress & Snow, 2000; McLaughlin, 2006; Schneider & Ingram,

1993). Further, problem framing can position teachers as agents or conversely as ineffective actors to address the problem at hand (Horn et al., 2015). It is important to note that diagnostic framing is often implicit, the solutions to problems are often discussed without explicit discussion of the problems themselves (Cress & Snow, 2000). While framing theory is useful to see the how norms, ideas, and approaches to mathematics instruction collectively emerge or change, it does not allow us to see the nature of the collective, informal relationships and access to social capital. For this, we rely on social network theory.

A network perspective on teachers' advice-seeking behavior allows us to see both the social structure of the school and the accessibility of social capital that are exchanged through informal collegial interactions (Penuel, et al., 2009). Social network data can increase our understanding of how the social structure of the school, including the role of the principal, supports or impedes the influence of particular ideas, information, and resources. Further, it can highlight how the position and role of formal and informal leaders may facilitate interactions and learning opportunities among teachers (Sun, Frank, Penuel, & Kim, 2013).

An essential entity in shaping teachers' ideas about mathematics instruction are the views of close colleagues from whom they seek advice about instruction (Coburn et al., 2010; Sun et al., 2013). A person has access to different information and sets of ideas depending on their location in a social network, and the nature of their ties to others (Adler & Kwon, 2002; Ahuja, 2000; Penuel et al., 2009; Small, 2009; Uzzi, 1996). Research on teacher social networks finds that teachers rely on those with whom they share common beliefs about teaching (Bidwell & Yasumoto, 1999; Gamoran, Gunter, & Williams, 2005; Penuel et al., 2010; Rigby, 2016). Thus, we expect that a close collegial network may

influence teachers' views of mathematics instruction by exposing them to a collegial institutional norm (Cole & Weinbaum, 2010).

The structure of the network as a whole may signal the nature of relationships around mathematics instruction in the collective, in this case the mathematics department at Creekside. The nature of teachers' relationships forms an environment with varying degrees of trust in which teachers may feel safe to take risks, an essential condition when teachers are asked to take on new content or instructional practices (Bryk & Schneider, 2002; Daly, Moolenar, Bolivar, & Burke, 2010). Dense network structures, or those with a high degree of dyadic ties, are typically characterized as having higher levels of trust among teachers as well as being more open to take on new instructional practices (Moolenaar et al., 2010; Moolenaar & Sleegers, 2010). Further, networks with strong ties, or those characterized by a high degree of trust, allow for both the transfer of complex information and joint problem solving (Granovetter, 1973). We conjecture that these types of relationships are essential if teachers are to share, discuss, and adapt new ideas that are far from their current practice, as is the case in the school of study. Finally, individuals' centrality in a network is indicative of exposure to information in a network, in this case knowledge about mathematics instruction. The more central a person is, the more people in the network are exposed to the information that person has (Freeman, 1987/1979). Centrality, then, is associated with influence and power (Friedkin, 1991). In this case, the centrality of individuals in the advice networks is likely indicative of their influence on their colleagues' ideas and practices around mathematics instruction.

The diagram of the conceptual frame (Figure 1) illustrates ways in which teachers' ideas about mathematics instruction may be influenced by and influence others' ideas through two mechanisms: teacher workgroups and informal advice networks. Teachers' instructional learning opportunities are

influenced by both conversations that happen in their workgroups and through their informal advice networks. This learning is not neutral, however. It exists in a broader context of accountability pressures (Valli & Buese, 2007), and the workgroup conversations themselves are influenced by school leaders. The ways in which problems of student learning are framed uncover the nature of teachers' ideas about instruction and concurrent opportunities to learn about new ideas in this context.

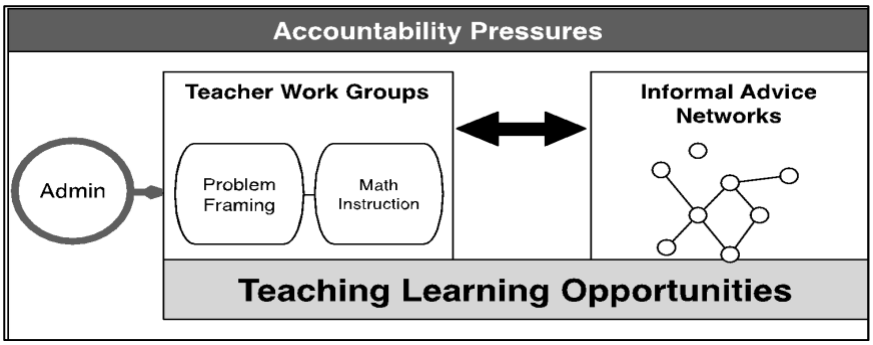

Figure 1: Conceptualization of teacher learning opportunities.

Methods

This research is a part of the Middle-school Mathematics and the Institutional Setting of Teaching (MIST) project, a larger study that investigates what it takes to improve middle school mathematics instruction at the scale of a large urban district in the US. MIST is a mixed-methods study of four large urban school districts attempting to support middle school mathematics teachers to develop ambitious instructional practices aligned with the recommendations of the National Council of Teachers of Mathematics (National Council of Teachers of Mathematics, 2000). In this analysis, we draw primarily on two data sources collected between 2008 and 2011: audio recordings of teacher collaborative meetings focused on instructional issues, and survey data documenting the advice networks of mathematics teachers at Creekside Middle School.[2] Secondary data collected annually

[2] Neither of these data sources was collected during the first year of the study.

utilized in this analysis include interviews with participants (teachers, coaches, principals, and district personnel). The interviews aimed to document district plans for improving middle school mathematics instruction and the ways in which these plans played out and impacted the work of teachers, school leaders, and mathematics instructional coaches in schools. These are used to situate our case and triangulate data in order to support or refute plausible explanations for observed phenomena (Mathison, 1988). Further, we use changes in relative student gain scores on standardized tests as supplemental contextual information.

We use a case study approach (Yin, 2003) to understand a relatively unexamined phenomenon: the role of school leaders in shaping teachers' formal and informal learning opportunities in a context of accountability pressures. To select our case, we mapped out the informal advice networks in a representative sample of six schools in which we collected data in one district over a three-year period. One school's maps stood out from the rest: Creekside Middle School. Unlike the other schools, Creekside's network fragmented over the three-year period, illustrating a dramatic change in advice-seeking behavior. To further explore why this might have happened, we analyzed audio recordings from the mathematics teachers' workgroups collected over the same three-year period. These data include 15 audio recordings of teacher meetings across the three years of the study (professionally transcribed), each of which is approximately 30 minutes long. All teacher meetings were content-specific and organized by grade level, and most were facilitated by the school's instructional coach. At least one school leader was present at 11 of the 15 meetings sampled. According to the principal at Creekside, the goal was for the teachers to be "planning their conceptual units, sharing ideas, bringing new things to the table…"

Guided by the instructions from MIST that directed the meeting facilitator (in this case the instructional coach) to record a sample of 3-5 meetings focused on issues of instruction, the instructional coach decided which meetings to audiotape and managed the logistics (sent the audio recordings and a cover sheet describing the members and content of the meeting to the MIST headquarters). While there were the same number of teacher workgroup meetings in the third year, the instructional coach audio recorded fewer (she had the same instructions, we do not know why she chose to record fewer). This resulted in uneven data of the teacher workgroups over the three years, although sufficient to include in the analysis especially when paired with the other study data (interviews and surveys).

The data collected in MIST were sampled in tiers, by full and partial participants. Fully participating teachers agreed to be interviewed, to complete the network survey, and to have their classroom instruction videotaped twice in a study year. Typically, three to five mathematics teachers per school agreed to be full participants. The other mathematics teachers in the school, partial participants, agreed to complete the survey and to be audio taped in their teacher workgroup meetings. This tiered sample impacts the supplementary data analyzed for this analysis as we only had interview data for three to five teachers per year. However, it does not affect our primary data sources as most of the teachers took the survey and were present for the audio-recorded teacher workgroup meetings.

District and School Background

Creekside Middle School was in a mid-sized urban district that served approximately 80,000 students. Creekside and the district served a diverse student population; three-year averages of demographics for each are summarized in Table 1.

Table 1
District and school student demographics

	% Latinx	% Black	% White	% English learners	% Free and reduced lunch
Creekside	44%	35%	18%	5%	66%
District	60%	24%	13%	29%	74%

Note. Percentages are rounded means across 3 years.

Creekside was typical of the schools in the district in terms of allocated time and support for teacher collaboration as well as accountability pressures. For teacher collaboration and support, in the district and at Creekside, about one hour per week was set aside for school-based collaboration among teachers, and a school leader typically attended these meetings. Each school had a mathematics-specific instructional coach who spent half of their time coaching teachers and the other half teaching. This person typically facilitated the workgroup meetings.

In terms of accountability pressures, schools across the district were under significant accountability pressure from district central office, state, and federal policies, and almost all of the schools in the district were under sanctions for missing annual yearly progress (AYP) targets under federal No Child Left Behind (NCLB) legislation. About half of the schools in the district were in early stages of sanctions, and about half were in late stages of sanctions during years 2-4 of the MIST study. In the 2008-2009 school year, Creekside was in early stages of sanctions and had not yet missed AYP because of scores in mathematics, but rather because of scores in other content areas. Finally, Creekside had similar levels of teacher expertise (as measured by instructional quality, mathematical knowledge for teaching, and years teaching mathematics) and retention as other schools in the district; there was not a statistically significant difference between the school mean and the district mean for any of these MIST project measures (see the appendix for a comparison of Creekside and the district

on these measures, and https://peabody.vanderbilt.edu/departments/tl/teaching_and_learning_research/mist/mist_instruments.php for a methodological description of these measures).

Finally, as part of a district-wide push to improve middle school mathematics instruction, in 2007 Creekside adopted a new curriculum, Connected Mathematics 2 (CMP2). The teacher supports described above were a part of the district's plan to provide ongoing and embedded opportunities for teachers to learn how to implement the curriculum. In addition, the district provided both district-based professional development sessions for teachers and administrators during the school year and sent selected teachers to off-site training sessions during the summer (provided by CMP2).

Framing Analysis

In order to answer our first two research questions about the nature of changes in teachers' formal learning opportunities (as seen by changes in their workgroup conversations) and the role school leaders play in those conversations, we began by listening to audiotapes of the meetings. In our first pass, we generated content logs to broadly document what took place in each meeting (Erickson, 2006). During a second pass through these data, two researchers listened to the audiotapes and compared notes on comments that related to teaching mathematics, how and when students learn mathematics, and how to support students' learning of mathematics. These notes and memos were used to generate a codebook, comprised of both deductive and inductive codes, organized around three broad themes: talk about mathematics, diagnostic frames, and prognostic frames relating to the problem of teaching mathematics (see online supplement for the coding scheme).

The codes for talk about mathematics are as follows: 1) *topic only*, when the talk was simply a mention of a mathematics topic such as volume, reflections, or multiplying fractions; 2) *terms and*

procedures, when the conversation focused on strategies for helping students remember vocabulary or formulas; and 3) *concepts*, when the conversation focused on underlying mathematical meaning. For example, conversations were coded *concepts* if they addressed the meaning of the concept (e.g., volume is the amount of three-dimensional space that something takes up), or how or why a formula works. The distinction between terms and procedures and concepts is consistent with Skemp's (1976) distinction between instrumental and relational understanding, characterizing instrumental understanding as "rules without reasons" and relational understanding as knowing "both what to do and why" (p. 9). While it is possible that concepts are discussed in ways that are richly linked to terms and procedures, the two categories were largely disjointed in the conversations we analyzed, consistent with Skemp's (1976) distinction. This distinction is revisited in the findings and discussion sections.

We identified three diagnostic frames for teachers' talk related to the problem frame of teaching mathematics, focused on three issues: (1) students need help to succeed on tests, (2) students need help to learn mathematics, and (3) other problems that were tangentially related to teaching mathematics, such as teacher compliance to policies about instructional minutes. Our prognostic frames are organized into ways teachers talked about solving the problem as framed: (1) cover appropriate topics, (2) adjust the way in which they teach particular topics, and (3) other, which typically was an argument that solutions lay outside of the teachers' control, such as students' poor behavior or inability to learn. Finally, we coded school leaders' participation in the workgroups into three categories: (1) not present, (2) engaging as a participant, and (3) facilitating the meeting. Often the school leader attending was not the designated facilitator but the active role they took in the leading the conversation in the meeting was as such.

After developing the codebook, the first two authors double-coded three transcripts to calibrate, and after establishing reliability, coded the rest of the corpus of data using NVivo10. All instances of uncertainty were flagged and discussed between the two coding authors. After coding all of the transcripts, we created a matrix summarizing each meeting relative to our codes that synthesized the conversation of the group as a whole and noted contributions made by individual participants. We then wrote summaries of the meetings by year and by grade level. These summaries allowed us to identify trends and shifts in conversations across time, both within and across grade levels. In particular, we attended to the role of the school leader, the meeting facilitator (who was usually the instructional coach), the instructional coach (if not the facilitator), and other vocal meeting participants. Finally, we made several meta-matrices that traced our codes in the meetings across grade level meetings and across time, attending to the relationship between the trends and the presence and role of the school leader in the meetings (Miles & Huberman, 1994).

Social Network Analysis

In order to answer our third research question, *What is the nature of changes in informal opportunities to learn, as seen by shifts in informal advice networks?* we used social network analysis (SNA) to map the available mathematics instructional expertise (per MIST measures) at Creekside, and the ways in which this changed over three years. In this study, the social network maps are "advice-seeking networks"; they represent to whom middle school mathematics teachers reported turning to for advice about mathematics instruction. We used participants' responses to the following survey questions sent to participants in April of each year: *During this school year including last summer, to whom have you turned for advice or information about teaching mathematics? How often?* The average response rate in at Creekside was 68.7%, as compared to the district response rate of 63.3%

(teachers who did not agree to participate in the study at the beginning of each year are not included in this calculation). We used UCINET (Borgatti, Everett, & Freeman, 1999) to map the data. The sociograms in the findings represent the shifting structure of the advice-seeking networks in Creekside Middle School from 2008 to 2011. The sociogram below, from the first year of these data, illustrates several key SNA analytic features, including network density and centrality. These are described below.

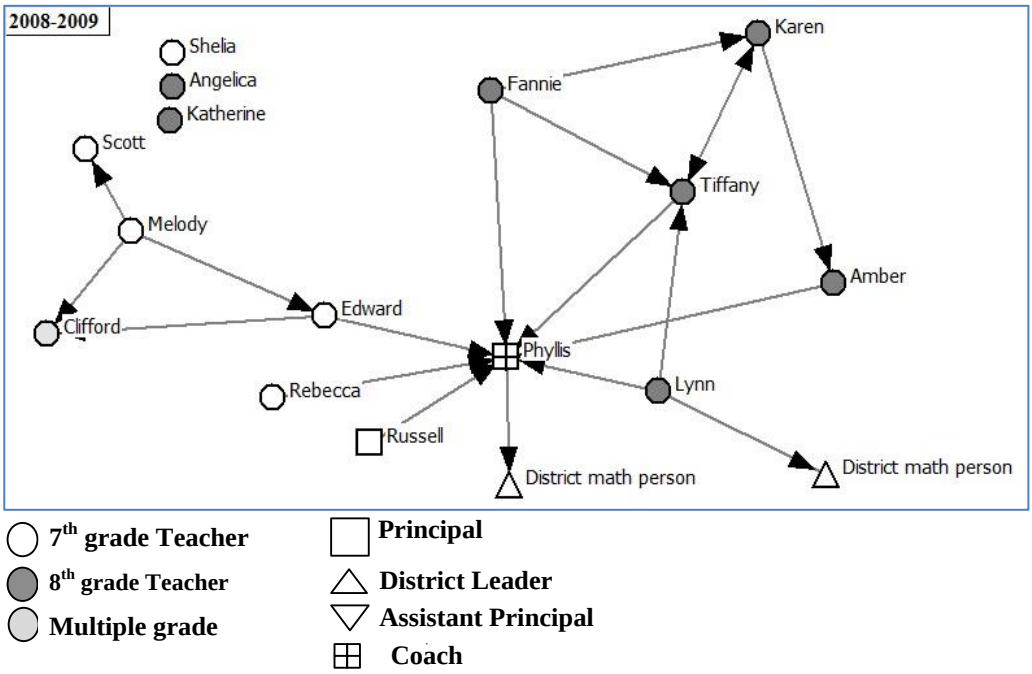

Figure 2: School year 2008-2009 Informal Advice Network

In the sociograms, the shape of each node represents that individual's formal role. Phyllis, for example, was the instructional coach and is represented by a hatched square in the center. The teachers are all represented by circular nodes, shaded dark gray for 8th grade and white for 7th grade, and light gray if they taught in both grades. *Network density* is measured by the degree of dyadic ties, weighted by frequency of interaction. A network in which every individual was connected with every other individual with a strong tie would be at maximum density, or a score of 1. Each tie has arrows: either

only going in one direction, pointing from the person seeking advice toward the person providing advice, or going in both directions, signaling that both individuals reported seeking advice from each other. In Figure 2, the network has a density score of 0.28 (the ratio of ties present to possible ties, weighted by frequency of interaction (Hanneman & Riddle, 2014)). *Degree Centrality* is measured by the level of an actor's in-degree score, or the number of people who turned to an actor for advice (Freeman, 1987/1979). While there are several approaches to calculating centrality, this approach is appropriate when assessing situated knowledge construction (Borgatti, 2005). In Figure 2, Phyllis is the most central person in the network with the highest in-degree score (7).

Synthesis of Analyses

To put the framing and SNA analyses in conversation with each other, we compared the findings in two ways: by year and over time. For each year, we examined the nature of the conversations and the informal advice network. We identified who had a prominent role in the conversations and how central they were in the network, how mathematics was talked about, and how the problem of teaching mathematics was framed. We took a similar tack across the years, looking at the trends across time. Additionally, we looked to see if the findings hung together, explicitly seeking disconfirming evidence that might point to alternative explanations.

Seeking Alternative Explanations

Teachers make around 1500 decisions each day (Jackson, 1990). It is likely, then, that there is no one influence, but rather a confluence of ideas and pressures that guide teachers' decision-making processes. To address the possibility of explanations other than the influence of the administrators for the change in the network structure and teachers' attention to testing rather than conceptual teaching and learning, we conducted several analyses relying on other data collected in the larger study.

First, we examined a number of other representations of teacher quality that the two main analyses did not attend to, such as years of teaching experience, instructional quality as measured by the Instructional Quality Assessment (IQA, Boston & Wolf, 2006), and their vision of high-quality mathematics instruction (VHQMI, Munter, 2014). These metrics might have shown that teachers' experience, demonstrated higher-quality instruction, or ability to describe high-quality instruction hung with the structure of the advice network or the change in attention in teacher workgroups. We did not find that any of these variables held explanatory power either quantitatively or qualitatively, and therefore do not include the results in the findings.

Second, to see if and how standardized test scores may have shaped the network and the content of the workgroup meetings, we examined the change in student test scores, or student achievement gains, by teacher and year. For this calculation, we used the district-provided test scores of all of the students in each teacher's classes, and controlled for teacher-level and school-level random effects in a multilevel model. Student achievement gains capture the difference between the score in the current year and the score in the prior year; these were used to determine each teacher's growth or decrease relative to the school mean as measured in standard deviations above or below the school mean. We report these results in the findings.

Finally, to explore plausible qualitative alternative explanations, for example if teachers felt that the new mathematics curriculum was too difficult to implement, or teachers did not value the coach's advice, we analyzed interview transcripts of the study's full participants, including three to five teachers, the instructional coach, the principal, and assistant principal. These were collected in January of each year starting in 2008 (the year before network survey data and audio data of teachers' collaborative conversations were first collected) through 2011. Notes were taken regarding comments

made in these interviews about curricular resources, instructional challenges and supports, interviewees' interactions with colleagues around mathematics instruction (administration, coach, and other teachers), and expectations and focus of teacher workgroup meetings. For each year, a summary paragraph was written highlighting themes within each role group (teachers, coach, administrators). We then created a matrix of these findings across the four years to trace themes, and compared these themes with the findings from the two main analytical phases. These results are described below.

Findings

We found that from 2008 to 2011 there were decreasing formal and informal learning opportunities as evidenced by the content and nature of teachers' conversations, as well as by the shifts in the structure of the informal advice network at Creekside Middle School. At first, teachers' talk about mathematics focused on more conceptual aspects of their instruction, and much of the teachers' diagnostic framing about the problem of teaching mathematics was around helping students learn mathematics. The corresponding prognostic framing was to change teachers' instructional practices. Over time, the diagnostic framing shifted to helping students do well on tests, with the mathematical focus of talk fading to the topic level or corresponding standard number, and the corollary prognostic framing of simply covering topics. At the same time, the informal advice network fragmented, shifting from a relatively dense network to a sparse one. We organize our findings by first describing the analysis of teachers' collaborative conversations during each school year. In this way, we seek to identify possible explanations for the decrease in teachers' formal and informal learning opportunities. In particular, we identify accountability pressures from the school leaders as observed in teacher workgroup meetings as instrumental in shifting the focus of teachers' collaborative conversations. Subsequently, we illustrate changes in teachers' informal learning opportunities as observed in the

social networks from 2008-2011 through sociograms (See Figures 2, 7, and 8). We conclude with the exploration of alternative explanations.

Shifts in Teachers' Formal Learning Opportunities through Collaborative Conversations

Our analysis of teachers' conversations in their workgroups across the three years revealed a concurrent increase in school leader facilitation and a decrease in teacher learning opportunities about ambitious mathematics instruction. The conversations featured a decreasing focus on mathematical concepts, procedures, and approaches to teaching mathematical ideas in ways that would support students' understanding, and an increasing focus on planning how to allocate time and resources to meet ever growing Annual Yearly Progress (AYP) targets.

Talk about mathematics. Across the years of the study, the nature of talk about mathematics and mathematics teaching shifted in teachers' collaborative conversations. Talk about mathematics was coded into four categories: concepts, terms & procedures, topic only, or none at all. Figure 3 indicates, for each year, the distribution of teachers' talk about mathematics into these four categories. There is a dramatic shift from 2008-2009 school year, when nearly 60% of teachers' talk about mathematics was about concepts and terms & procedures, to 2010-2011 school year, when 60% of teachers' talk was naming the topic or number of the related content standard (i.e., "Standard 3.4").

The only year in which there were a substantial number of conversations framed around concepts was in 2008-2009, 27% of the time. For example, in one meeting the teachers discussed a real-world example (using objects in the classroom, floor tiles and filing cabinets) to help teach students make sense of the distinction between area and volume:

> *Edward:* What're we measuring if we're just looking for the tile of the floor? Are we looking for volume or are we looking for area? And all 'em, they go, "Well, we're just needing the floor. So, we just need…length and width…That's area…so, what if we were to stack filing cabinets in this room? Now, what kinda measurements are we

> gonna have to take? Well, we're gonna need the area still, but we're gonna need the how high the ceiling is, too… They figured out that's the volume.
>
> *Rebecca*: That's good.
>
> *Edward*: The height was the third piece to the volume part and they started, they started to catch on. If you use real things around you, they start seeing, getting the idea. It really works. They could actually figure out how many tiles are in that room.

This conversation highlights the conceptual contrast between what area and volume measure. The teachers linked these concepts to real-world examples that helped students appreciate the difference. Across the meetings, discussions about mathematics concepts had a focus on real-world examples that might help students understand particular concepts. However, the discussions lacked an explicit link to underlying patterns and relationships that give rise to common formulas and procedures often needed to be successful on standardized tests. The percentage of conversations about concepts, similar to the example provided above, decreased by nearly 75% in 2009-2010 (from 27% of the time to 7% of the time), and disappeared entirely in 2010-2011.

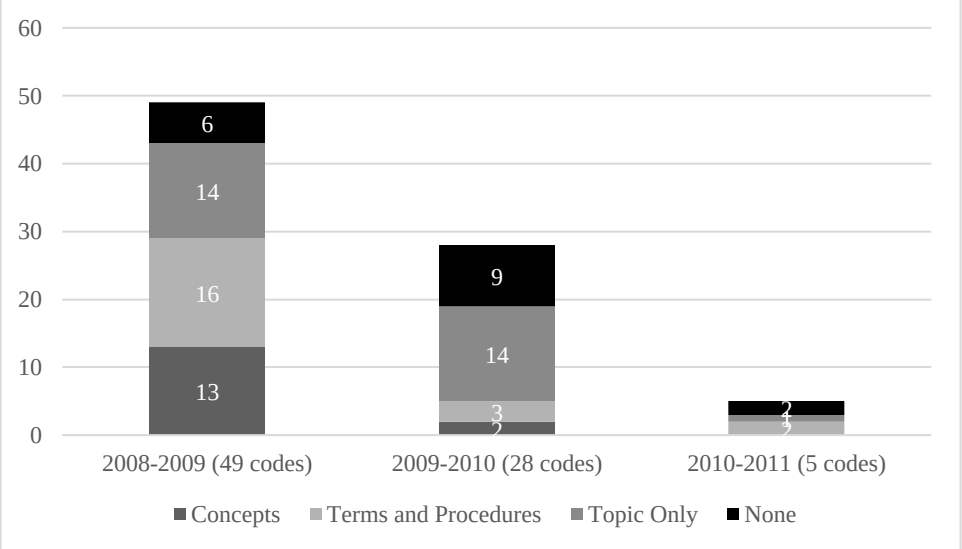

Figure 3: Nature of talk about mathematics at teacher workgroup meetings.

While 2008-2009 was the school year in which the most conversations about concepts occurred, it was the focus of a relatively small percentage of mathematical conversations. Most of the mathematical conversations in that year focused on either terms & procedures or topic only (61% of the time). The following is an example of an exchange coded as *terms & procedures*:

> *Tiffany*: Yeah, I think just the angles in general are hard for them. They're hard for mine.
>
> *Coach Phyllis*: Hmm hmm.
>
> *Tiffany*: Yeah, I mean luckily they can get a 90-degree angle, but, you know, the 90, the 180, and the 360, they got, but it's the, everything else in between they're like, it really throws them off.
>
> *Coach Phyllis*: The acute?
>
> *Tiffany:* Oh yeah.
>
> *Coach Phyllis*: And I usually try to tell my kids something about a cute little girl, the boys like that better than the obtuse, oh-, you know, do something just really dramatic...

This example highlights workgroup conversation focused on terms and procedures. Coach Phyllis's (notably gendered) suggested strategy draws on a mnemonic device to help students remember mathematical terminology for acute angles. Similar strategies were frequently suggested, particularly by Phyllis, to help students remember terms and procedures. While this kind of conversation may help students remember vocabulary, it is not evidence of conceptually focused talk about mathematical content.

The terms and procedures focus of mathematical talk on dissipated in 2009-2010, and was replaced with both mathematical talk that focused only on naming the topic and "none", or conversation that was not specifically about mathematics at all. In the 2009-2010 "topic only" conversation below, the 8th grade teachers were looking at the results of a district test in preparation

for the end-of-year culminating state exam. While the teachers did not discuss concepts or instruction, they did mention a mathematical topic: geometric reflections.

> *Tiffany:* Okay, so maybe, just make copies of that study guide for our students who may need help…mine did really well on four…it was across the board, I don't know, I guess I've just been grilling that one…mine did bad on 3 and 6, so, which 6 they always, you know.
>
> *Lyle:* Yeah, 3 was my highest. Like I didn't fail 3.
>
> *Tiffany:* Well I figured that one, it's so easy, the reflections…I thought it didn't look hard to me, but I guess they all missed it.

An important commonality among these three ways of talking about mathematics (terms and procedures, topic only, or none) is that none address the thinking that students need to do in order to understand underlying mathematical concepts. By 2010-2011, talk during teacher workgroups was largely not about mathematics at all. An example of what the final category "not explicitly about mathematics at all" is when a coach, teacher, or school leader framed the conversation around which number question should be used for a quiz to cover a particular standard. For example, "Let's use #12 cause it covers standard 4.3." In summary, conversations in mathematics teacher workgroups at Creekside notably changed in a three-year period from addressing concepts to minimal talk about mathematical concepts, procedures, or topics.

Problem Framing. From 2009 to 2011, there was a sharp and consistent decline in the number of codes assigned to teachers' talk. In part, this is due to fewer meetings to code (six audio-recorded meetings in both 2009 and 2010, three in 2011), but the percentage of codes per meeting also decreased. For example, the number of diagnostic codes decreased from an average of 8.2 codes per recording in the first year, to 4.7 in the second year, to 1.7 in the third year. This signals that teachers'

talk was increasingly not about topics related to teaching and learning in mathematics. The descriptions of the diagnostic and prognostic frames below illustrate this change.

Diagnostic Framing. From the first year to the second, teachers' talk about the problem of mathematics instruction changed from a focus on needing to help students learn mathematical concepts (particularly by drawing on real-world examples and contexts) to a focus on helping students pass tests. The previously described conversation about volume is an example of a conversation whose diagnostic frame was coded as *need to help students learn math*. An example of a conversation whose diagnostic frame was coded as *need to help students pass tests* took place in 2010-2011, when the first part of the 8th grade meeting was focused on both deciding which students go to "math bootcamp," an all-day mathematics remediation before the state test, and how to let the students know this was coming. One teacher explained, "I told mine about [math bootcamp] today because they wouldn't quit talking." Conversations whose diagnostic framing was coded as *other* included conversations about how to distribute students for gender-based classes, and a reminder from the assistant principal that teachers must continue to teach mathematics content in the final 30 minutes of school after the test-prep days.

As seen in Figure 4, there was a marked drop in the proportion of frames focused on helping students learn mathematics from the first to the second year (from 51% of the frames to 18%). This drop in proportion does not repeat in the second to third year as the majority of the conversations in 2010-2011 were about which question to put on which test, which led to few codable diagnostic framings. In the third year there were only two frames (across three meetings) that were about helping students learn mathematics. Notably, these were qualitatively different from those in the first year. Rather than discussing real-world examples like filing cabinets and volume, one of the coded examples

in the third year was about who was going to laminate vocabulary cards for students. While both conversations are about helping students learn mathematics, the first is focused on learning concepts while the second is a technical support.

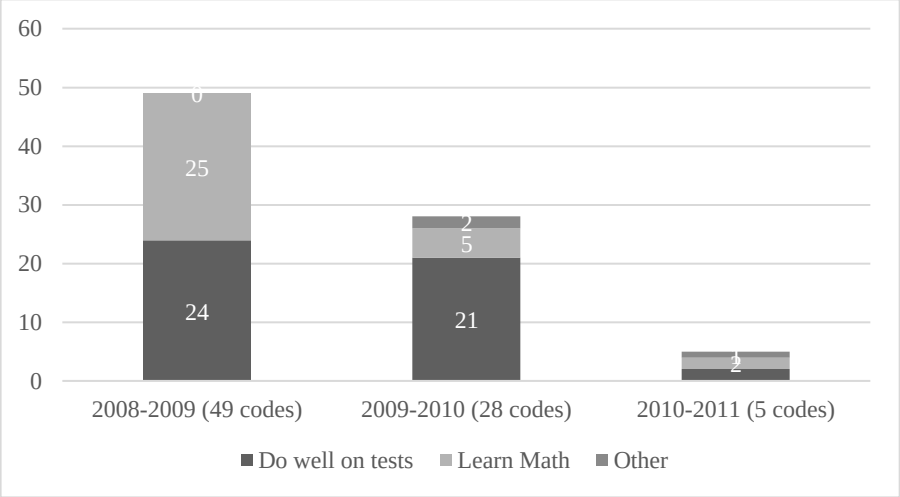

Figure 4: Diagnostic frames in teachers' collaborative conversations.

Prognostic Framing. As shown in Figure 5, the number of prognostic frames proposed by teachers dropped concurrently with the number of diagnostic frames over the three years of analyzed teacher conversations. This reduction reflects a decrease in the amount of substantive talk over time. Similar to the diagnostic frames, there was a drop in the proportion of prognostic frames focused on adjusting instruction from the first to the second year; while the proportion did not drop as the number of codes went further down in the following year, the nature of prognostic frames within our coding scheme continued to shift.

As teachers increasingly framed the problem as needing to help students pass the tests, the solutions they proposed also changed from one where teachers had agency to solve the problem to solutions that were outside of their control. In the first year, 69% of teachers' prognostic frames focused on adjusting instruction, this percentage decreased to 21% in the second year. Instead,

teachers' prognostic frames with a focus on covering topics and "other" increased from 25% in the first year to 69% in the second. In the second year, "other" included figuring out which students needed extra tutoring to be able to pass the tests and student behavior. For example, a teacher explained that the reason some of the African American and Latinx students did not pass the test was because they "were really big behavior issues, so that's, you know...a lot of the ones that failed in math also failed the reading, so there's kind of a correlation." This shift from "this is a problem I can solve" to "this is out of my hands" offers a plausible explanation for why teachers at Creekside stopped seeking advice from one another about mathematics instruction.

It is important to note that the number of prognostic codes decreased significantly in the third year due to the same phenomena described in diagnostic framing: the conversations were largely not about teaching and learning in mathematics. In the third year, the percentage of codes is not as instructive about the change in teachers' learning opportunities as is the lack of conversation focused on teaching and learning mathematics in general.

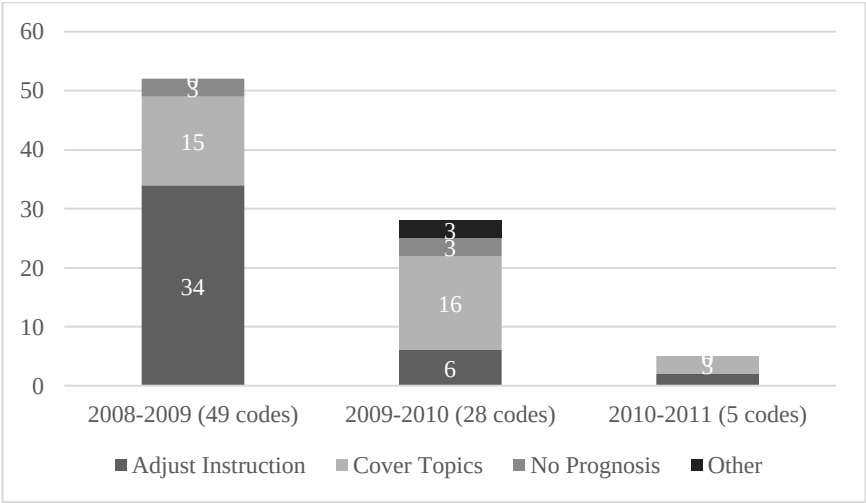

Figure 5: Prognostic frames in teachers' collaborative conversations.

Role of school leaders. Across the three years, school leaders played an increasingly prominent role in shaping the focus of teachers' collaborative conversations. First, they did this by having a stronger presence in the meetings. Figure 6 illustrates the change in administrator presence, from not attending at all for most of the first year (coded 0), to attending as a participant more frequently in the second and third years (coded 1), and attending as the de facto facilitator in three of the eighth grade meetings (coded as 2).

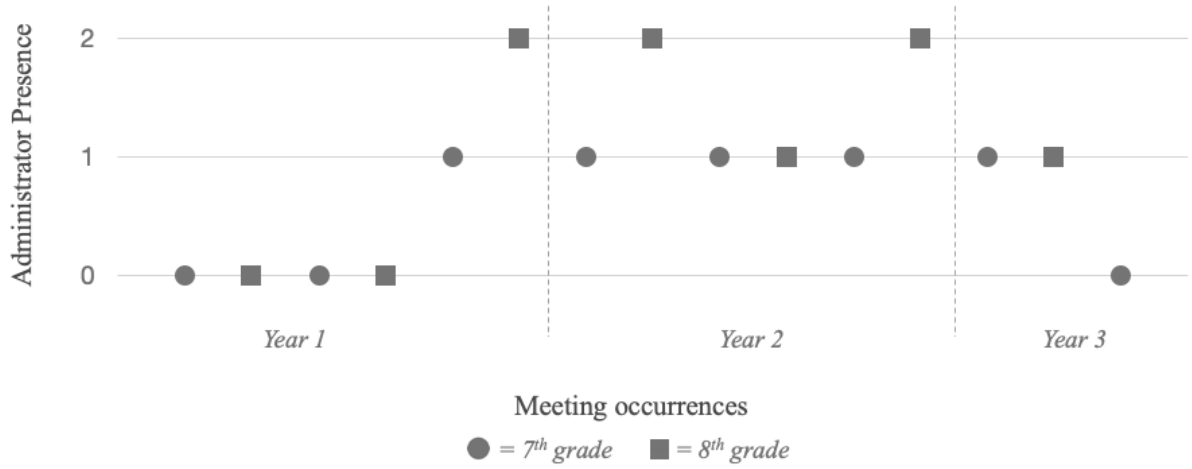

Figure 6: Administrator participation in teacher workgroup meetings.

Not only did the administrators command a stronger presence in the meetings, they also qualitatively shaped the nature of the conversations. Both the principal and the assistant principal narrowed teachers' conversations to focus on covering topics related to the standardized tests, either with a focus on standards or using benchmark data to make decisions about what to cover.

The example below illustrates how the principal, Mr. Russell, actively pushed a test-focused framing by encouraging teachers to identify which tested standards they had not yet covered absent any instructional conversation (this is in the last 8th grade meeting in the first year). In this exchange,

one teacher, Karen, began to articulate a more nuanced description of plans to integrate standards across lessons:

> *Karen*: [Standard Number A], use appropriate operations to solve problems involving rational numbers in problem situations. We said that we haven't covered it directly and we need to cover it again. And that's B. On C, we said we were gonna mesh it in with the others, evaluate a solution for reasonableness. We haven't done that in any of our lessons, but we could mesh that in with others. And that's where we left off. [Standard Number B], use multiplication as a constant factor-to-unit rate. We've done that.
>
> *Mr. Russell:* Students weak in it or...
>
> *Karen*: We, it would definitely be to our advantage to go back and review it, put it back in the openings and stuff.
>
> *Mr. Russell:* Okay.
>
> *Karen*: But we ha-, as far as something that we've covered, we haven't covered it.
>
> *Mr. Russell:* Okay. So, let's then, so let's just focus on what we haven't covered I guess right now and we can go back and talk about ones we're weak in after that.

Mr. Russell's final remark in this exchange is indicative of his approach to instructional triage: his goal was to clearly identify which standards assessed on the state test had not yet been covered before allowing teachers to discuss *how* they planned to cover those standards. However, the conversation never returned to address plans for how to teach those standards and devolved into an exchange organized around standard numbers with periodic mentions of topic names.

Bradford, the assistant principal in charge of the mathematics department starting in the 2009-2019 school year, took a similar approach in his facilitation of the workgroup meetings as Mr. Russell, although his focus was on using data to drive decisions about which students received additional support. He started an 8th grade workgroup meeting by presenting benchmark data "because what we wanna do is check our sub-groups in terms of the math so we don't get hit up like science did." In the conversation that follows, teachers reported out "successes" from the past week in relation to the data.

Two teachers reported that their students had trouble filling in the correct bubbles, so "we may want to really focus on how to bubble for a little while." Another described how one of her students who received special education services "improved so much...I think he got a 51% [on the benchmark], which was 10 points away from where he was at the beginning of the year." Bradford is the last to report out his success, "One thing I could see was [teachers were] taking the data and actually using the benchmarks to drive instruction in areas of concern."

It is clear by the nature of the discussion that the manner in which the teachers used data to "drive instruction" is not likely to lead to an increase in ambitious instructional practices. While the teachers used data to change the focus of their instruction, they did things like taught students how to fill in bubbles, decided which students received additional test prep, and which standards to review again. These practices were framed as appropriate by Bradford and when students increased their scores, the results were celebrated.

In the examples above, the administrators played an active role in defining the problem and proposing the solution. With Mr. Russell, students needed to have material presented to them in order to do well on the tests, and the solution was that teachers needed to cover the appropriate topics. For Bradford, the problem was that students needed to do better on the standardized tests, and the solution was for teachers to use benchmark data to inform instructional decisions about topic coverage. Further, even when the school leaders did not actively frame the problem, their presence seemed to have an impact on how the facilitator, most often Coach Phyllis, framed the conversation. In 2008-2009, the diagnostic frames offered by Phyllis were organized around conceptual talk about mathematics and instruction. As time progressed, Phyllis' framings shifted to covering topics. This emphasis was particularly pronounced when a school leader was present in the meeting, so even when the

administrator did not explicitly facilitate the meeting towards accountability, their presence seemed to have that impact. The increasingly procedural focus on topics and coverage may have resulted in approaches to instruction for which teachers felt they did not need to seek advice. This may help explain the fragmentation observed in the teachers' advice-seeking network.

Decrease in Informal Learning Opportunities

Over the period of our study, Creekside's advice network fragmented and network centrality shifted. The sociograms (Figures 2, 7, and 8) illustrate the network as documented by our network survey during each year of our study.

Network Fragmentation. Shifts in network density confirm the network's fragmentation. The informal advice network in 2008-2009 had a relatively high density (0.28). While there were three teachers who were isolates, meaning they did not report asking anyone for advice about mathematics instruction nor did anyone report asking them for advice, nearly everyone in the network reported either getting or giving advice about mathematics. In 2009-2010, the density score decreased to 0.20, reflecting fewer teachers reports of giving or getting advice. By 2010-2011, the network was relatively sparse, with a density score of 0.10. At this time, most individuals in the network reported reaching out to either only one other or no other person for advice. This is a striking change in a network structure.

Centrality in the Networks. In the 2008-2009 school year, Phyllis was the most central actor in the network. Teachers from both grade levels and the principal turned to her for advice about math. Her in-degree score, or the number of people who turned to her for advice, was seven, the highest in the network. Arguably, she had the most influence in the math department at Creekside (Freeman, 1987/1979). The only person she went to for advice was Hope, the district math lead. Tiffany was the

second most central person in the network with an in-degree score of three. She reported that she went to Phyllis for advice.

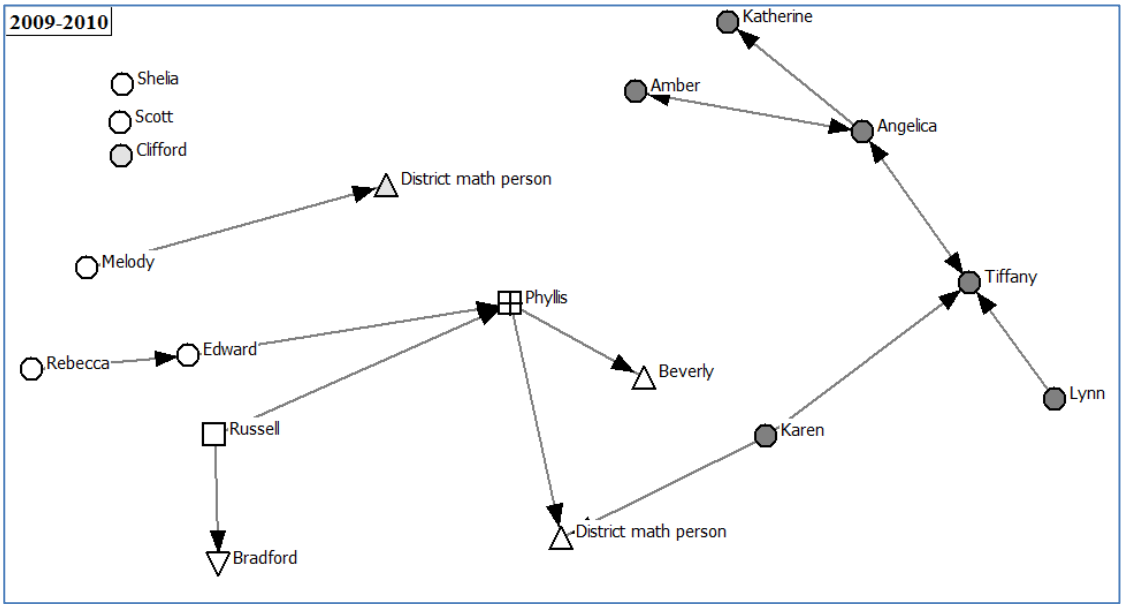

Figure 7: School year 2009-2010 Informal Advice Network

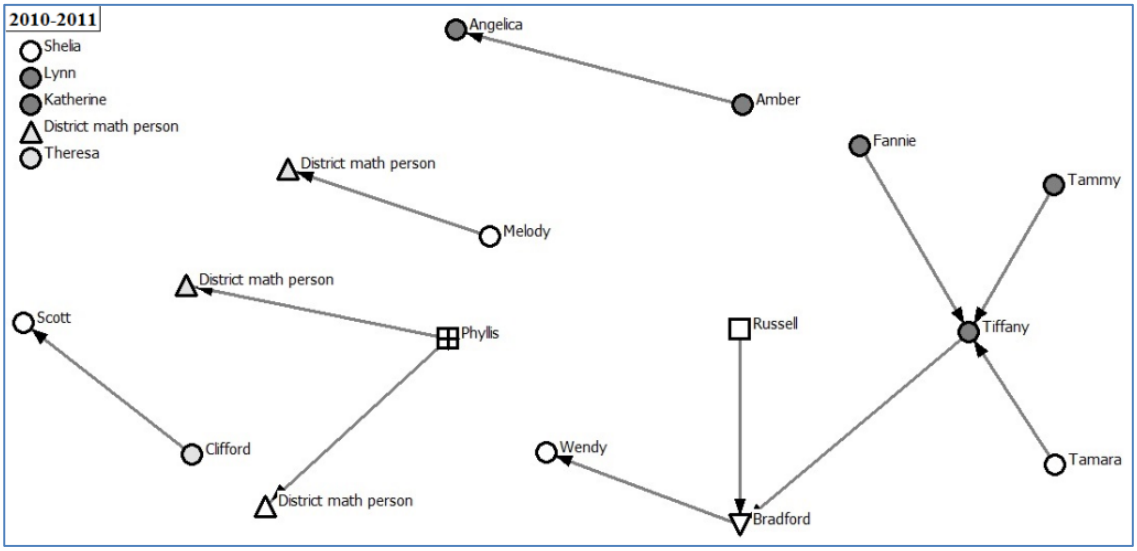

Figure 8: School year 2010-2011 Informal Advice Network

The 2009-2010 sociogram illustrates important changes in the network from the previous year. The network began to fragment, with no teachers seeking advice from anyone outside their grade level

group. The only link between these two groups was through one of the district math leads. This fragmentation reflected Phyllis's decreasing influence. Only one teacher went to her for advice about mathematics in 2009-2010; the other person who turned to her for advice was Mr. Russell, the principal. Not one teacher from the 8th grade team went to her for advice about mathematics. Tiffany, on the other hand, maintained her in-degree score of three (all eighth grade teachers) and became the most central actor in the network with an in-degree score of three.

While Tiffany certainly had more informal influence than Phyllis at this point, the shift in the network centralization highlights an interesting phenomenon. From 2008 to 2010, the in-degree centralization of the network decreased by almost 30% (from 47% to 15%). This index indicates that in 2009-2010 there was not a central expert who provided as much advice and support about mathematics as Phyllis did in 2008-2009. So while more people went to Tiffany than Phyllis, she was not sought out for advice to the extent that Phyllis once was. This signals that the teachers' overall access to advice about mathematics decreased, and this trend continued into 2010-2011.

Despite having the formal role of mathematics instructional coach, in 2010-2011 Phyllis had an in-degree of zero, meaning that not a single person nominated her as someone he or she went to for advice about mathematics. The individuals she went to for advice were both outside of Creekside Middle. Tiffany's influence, on the other hand, maintained the same in-degree as the previous year in an increasingly sparse network. The only person that Tiffany went to for advice about mathematics was the assistant principal, Bradford. While he was the school leader that oversaw the math department, he did not have a mathematics background. Notably, Mr. Russell also went to Bradford for advice about mathematics, and he did not go to Phyllis for advice in 2010-2011, like he did the two

years prior, nor did he go to Tiffany. Without the formal role of "coach," Tiffany may not have had as much legitimacy as Phyllis once had, as reflected in the lack of growth in her in-degree score.

Throughout all three years of data, Phyllis had the formal role of math coach, and Tiffany was a classroom teacher. However, in the second two years (2009-2011), the school leaders reported in interviews plans to slowly shift Phyllis out of the role of leading teacher workgroup meetings, and to increase Tiffany's formal leadership role. This change is evident in the data: Phyllis led all meetings in 2008-2009 year, and only 7th grade meetings during the subsequent two years. Concurrently, Tiffany was given the formal role as mathematics department head in 2010-2011, and became the school's instructional coach in the year following those reported in this analysis, the 2011-2012 school year. The school leaders' actions to downplay Phyllis' influence were clearly successful, whereas Tiffany's rise in influence is not evident in these data.

Seeking Alternative Explanations

While it is clear that the school administrators influenced the nature of teachers' learning opportunities, we also wondered if there were other factors at hand that our two main data sources did not account for. The main source of school-based qualitative data collected in MIST were the annual interviews of all teachers, instructional coaches, and administrators who were full participants. As described in the methods, the first two authors read all of Creekside's interview transcripts from 2008-2011 with an eye towards alternative explanations. Was it just that teachers didn't like Phyllis, and so they stopped going to her for advice? Was the new ambitious curriculum too difficult, so the teachers went back to their previous approach to instruction? Did teachers conclude that the new curriculum did not prepare students to do well on the standardized tests? Our findings from an analysis of the interviews indicate that versions of these explanations existed, but rather than serving as alternative

explanations, we argue that they build on and provide finer grained detail to our previous findings. Specifically, the interview data showed two interconnected findings: over time, teachers and administrators felt that Phyllis's advice was no longer useful, and the new curriculum alone did not adequately prepare students for the standardized test. An analysis of student achievement gains confirms these findings. In the next section we describe the findings from the analysis of the interview transcripts of the full participants, and conclude with Creekside's student achievement gains over the three-year period of this analysis.

Five teachers, the instructional coach (Phyllis), and the principal were interviewed in 2008. Of the five teachers, four reported going to Phyllis for advice and found her support helpful. For example, one teacher reported that, "in my case, it is trying to bring the curriculum in line, how do you think this is going to work? What are the pitfalls in this?" All five teachers also reported liking the new curriculum, although two expressed that they did not think that it was appropriate curriculum for the students that Creekside served. One commented that it was geared toward honors students, and another said,

> "I consider [CMP2] discovering mathematics. You discover it, but they have no clue what to do to get there. And they can't step out on their own and figure something out. And I don't know whether it's just pure laziness or the fact that they know that if they sit there long enough and they don't do it long enough that you're going to step in and help. And at some point, you got to do something because you can't let 'em all fail."

In 2008, Mr. Russell supervised the mathematics department, and he was committed to CMP2. Notably, none of the teachers or the administrator mentioned the standardized test.

In 2009 there were four teachers who were full participants and were interviewed (in addition to Phyllis and the principal). Similar to 2008, three reported going to Phyllis for advice, mostly focused on mathematics content such as ways to teach and explain proportions and percents, and how to solve particular problems. Teachers' descriptions of the curriculum also remained relatively stable from the previous year, all reported liking the curriculum and the focus on higher-level thinking. The teacher quoted in 2008 continued to struggle with her students' engagement in the material, and still believed that CMP2 was not appropriate curriculum for her students. One teacher mentioned the standardized tests this year, "I'm hoping after we've covered most of the information, after [STATE TEST] when there isn't quite so much pressure on the [STATE TEST] stuff, then maybe we can pull in more hands-on stuff, have a little bit more fun with it."

In 2010, five teachers (four eighth grade, one seventh grade), Phyllis, the Assistant Principal, and the Principal were interviewed. The interviews from this year paint a very different story than the previous two years. Rather than being willing to try CMP2, albeit with hesitation, four of the teachers interviewed (all 8th grade) expressed extreme discontent with both the curriculum and with Phyllis, who supported the implementation of the curriculum. One teacher described it this way: "The kids have been doing CMP[2] for two to three years, and they still can't think for themselves." Another said that she did not use the curriculum very frequently because "very little of the book actually teaches the [STATE TEST] in the way it's tested. A lot of stuff, for example the Pythagorean, goes on forever, so we lose a lot of time doing stuff that is not applicable to the testing." Their dissatisfaction with Phyllis ran along similar lines. One teacher explained that Phyllis brought lesson ideas that "didn't match up with what we had to do...so we took over so we could use the time to plan. In the first year, she really helped me a lot, but since then...if she takes over, we don't get anything done and it frustrates us."

This year (2010) the administrative responsibilities for the math department switched from the principal to the assistant principal, Bradford. He made it clear in his interview that he did not think that CMP2 was an appropriate curriculum to prepare the students for the state test. He explained, "...there's a disconnect. And if the kids aren't being asked or tested based upon the [STATE TEST] (in their classrooms), if they get to the [TEST], CMP2 is not doing it."

In 2011, only three teachers were interviewed, all 7th grade (in addition to Phyllis, the Principal, and the Assistant Principal). All three teachers talked about how the CMP2 didn't prepare their students for the state test, so they figured out ways to incorporate test-specific teaching into their lessons, some exclusively so, and others supplementing the CMP2 curriculum. Their explanations mirror those in past years, such as: "At this point in time, those students need step one, step two, step three. And that's what we decided on. We can't teach them through 'What do you think if…? How is this? The quantity of?' They just need plain instruction." Another teacher explained that Bradford gave her the okay to focus on standardized test instruction as long as she was also teaching CMP2.

Bradford explained that the teacher workgroup meetings were guided by mandates from the state and therefore were more operational rather than instructional. He also expressed feeling pressure from the district to focus on testing and frustration that teachers can't teach on testing days (he estimated they spend 35 days testing). When asked what the biggest challenge in mathematics was this year the principal responded, "Where we're at right now is that getting kids to take responsibility for their deficiencies...for their learning." He also explained that he goes to Tiffany for advice more "because we're trying to develop her as a leader."

Student Test Score Gains. In an effort to link changes in the network maps to the outcomes the teachers and administrators mentioned as consequential in their interviews, we include a measure

of student test score gains (a teacher-level measure of students' gains from the previous to the current year on the state test, measured in standard deviations relative to the school average gain) (Figure 9). Coach Phyllis was concurrently an instructional coach and a classroom teacher (she taught two 8th grade classes), so we are able to include the score gains from her students as well. Note that we do not have score gains for any of the school or district leaders as none of them provided mathematics instruction directly. The multiple hatch marks in Figure 9 indicate all of the mathematics teachers' gain scores at Creekside. We include trendlines for the school average, the district average, and Tiffany and Phyllis' gain scores. Phyllis' gains in student test scores started lower than the school's average, and decreased over the three years. In contrast, Tiffany's gains were initially the highest in the network and increased significantly by 2012.

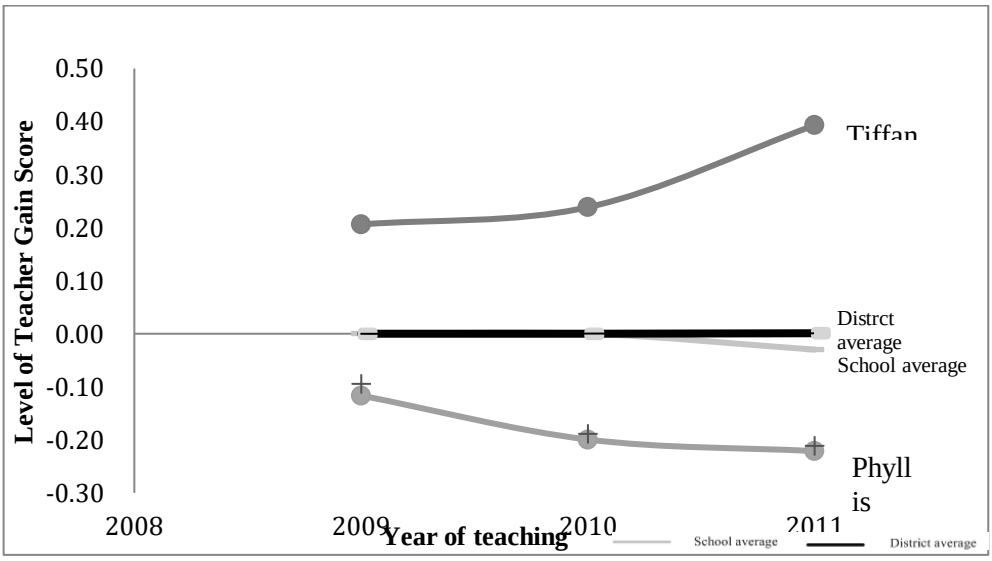

Figure 9: Creekside's teacher gain score distribution with district average.

Wilhelm, Chen, Smith, and Frank (2016) found that teachers who have high gain scores are more likely to be sought out for advice by other teachers, even when these scores are not explicitly shared. The results indicated in Figure 9 indicate that Creekside teachers' behavior was similar. This

finding suggests that Phyllis' efforts to support teacher learning came to be seen as ineffective for raising test scores, whereas Tiffany's approach to instruction did lead to that result. In conjunction with the administrators' shifting preference for Tiffany's leadership, it is clear that Creekside teachers shifted their attention to an instructional approach that favored test prep over ambitious instruction.

Discussion

In summary, we found that from 2008-2011, teachers' formal and informal opportunities to learn decreased: the conversations in the mathematics teachers' workgroups moved from discussions of how to help students learn mathematics to conversations focused on helping students do well on tests that did not involve any specific focus on mathematical content; concurrently the advice-seeking network of the mathematics department at Creekside Middle School splintered. We argue that these phenomena are connected, and that school leaders played an important role in this shift. As Coburn et al. (2010) suggest, while formal organizations such as schools cannot manipulate informal social networks, they can shape the conditions under which networks are constituted. In this case, in teacher workgroups the school leaders emphasized the importance of responding to accountability pressures. This press shifted the attention away from Phyllis, who framed conversations around learning mathematics, to Tiffany, who framed conversations in terms of what content to cover. This change is also reflected in the sociograms through Phyllis' loss of and Tiffany's maintenance of centrality. While it is possible that conversations can be focused on improving test performance by improving and adjusting mathematics instruction (e.g., Horn et al., 2015), that was not observed in our data. We offer two explanations for why this shift happened at Creekside: a lack of depth in the conceptually oriented mathematical conversations, and an instructional management approach to school leader press on accountability measures.

Low-Depth Conceptual Mathematical Talk

As demonstrated in the findings, the teacher workgroup meetings were drained of mathematical content from 2009-2011. By the 2010-2011 school year, there was not a single mention of mathematics from a conceptual lens, and nearly 80% of the diagnostic frames were either about helping students do well on tests, or expressions of the view that students could not learn what was expected of them. While this is striking, to understand the change it is important to also consider the initial conversations that were about mathematics concepts. Teachers' early conversations suggest they saw the value in helping students understand the nature of the underlying phenomena through real-world contexts (e.g., by giving students real-world examples to help them understand what volume measures), but the conversations did not address how structured analyses of these contexts give rise to the mathematical formulas and procedures that students were held accountable for knowing (i.e., how students might come to see patterns in how volume can be measured for specific kinds of shapes in ways that give rise to formulas for volumes of prisms, cylinders, cones, etc.). Instead, the conceptual talk observed in 2008-2009 involved teachers describing different approaches to learning particular topics (often drawing in real-world examples and hands-on activities), and sharing what might be considered each other's "best practices" to help students learn.

The lack of conceptual depth in the conversations facilitated by Phyllis may have contributed to the shift away from this conceptual talk and toward issues of testing and accountability. If teachers did not make the connections between concepts and related formulas and algorithms, it would not be surprising that students did not make those connections on the tests, either. McLaughlin (1987) argued that policy implementation needs both press and support. While Phyllis' facilitation of the 2008-2009 teacher workgroups can be seen as press, teachers' learning opportunities to develop ambitious

mathematics instruction appear to have been insufficient. Given the administrative press towards accountability, the teachers abandoned conversations about mathematics concepts, terms, and procedures and conversational focus turned toward issues of accountability. In concert, the stark version of accountability that Creekside took on, bereft of conversations about mathematics or instruction, left few reasons to go to colleagues for advice about mathematics.

At the same time as teachers' conversations moved from low-depth conceptual talk about mathematics towards accountability, their framing suggested they felt little control to change student outcomes through instruction. This is seen through the change in prognostic framing from "teachers change instruction" in nearly 60% of their frames in 2008-2009 to 20% in 2010-2011. Instead, the prognostic framing changed to either covering topics or other (discussion of issues outside of teachers' control). Other research has similar findings; for example, Finnigan and Gross (2007) found in their study of persistently low-performing Chicago Public Schools that teachers reported increasing their efforts in the face of sanctions, but after an initial motivational response, lost morale as their schools remained on probation. While Creekside was not on probation, the administrative press for focus on the standardized tests was clear. Without a sense of the ability to create change through their own means (e.g., through instruction), or support from someone with content-specific instructional expertise to help them develop ambitious mathematics instruction that would also help their students succeed on state tests, it is possible that the teachers did not feel the need to seek advice on mathematics instruction.

School Leaders' Instructional Management Approach

The combination of conversational, social network, and interview analyses suggests that school leader press focused largely on accountability, rather than on a deeper conceptual approach to

mathematics instruction, was an important influence in a constellation of factors that impacted the breakdown in teachers' formal and informal learning opportunities. The press for accountability was clearly an influence in the shift of the conversations away from mathematics in teacher workgroup meetings. This is evident both through the school leaders' framing in the conversations, and through the implicit value they placed on conversations about helping students do well on the tests by covering topics.

One way to understand the school leaders' actions is through the concept of an *instructional management* orientation towards improving student outcomes, or an approach that reorganized current resources to lead to increased outcomes (Cobb & Jackson, 2011; Horn et al., 2015; Jackson, Cobb, & Rigby, 2014). This is in contrast to an *instructional improvement* orientation that focuses on increasing adult capacity to improve student outcomes. For example, the assistant principal, Bradford, led the 8th grade teachers through a process to decide which students to send to Saturday Math Camp in an effort to provide a just-in-time intervention for students with hopes of reaching proficiency levels before state tests. Similarly, Mr. Russell's facilitation of conversations about coverage of standards indicates an instructional management orientation: he aimed to ensure that students were exposed to all of the content without explicitly attending to the quality of the coverage. In contrast, an instructional improvement orientation would have attuned the school leaders' attention to the teachers' learning opportunities. This orientation does not require that the school leaders have a deep conceptual understanding of mathematics. Instead of leading discussions about coverage, the school leaders would have facilitated discussions that elicited conceptual conversations about mathematics, relying on teachers' and the coach's content expertise. The school leaders' instructional management approach, seen through their press for accountability that unfolded in the teacher workgroup meetings, was nearly

devoid of conversations about mathematics. The teachers stopped talking about instruction with one another, so there was little reason to nominate anyone as the person they went to for advice about mathematics.

Implications

Multiple studies illustrate the negative impacts of the accountability movement on high-quality student learning opportunities, from narrowing the curriculum (Crocco & Costigan, 2007) to increasing teacher attrition (Clotfelter, Ladd, Vigdor, & Diaz, 2004; Feng, Figlio, & Sass, 2010). This study adds to this literature by illustrating that a focus on test scores and coverage of content rather than instruction and conceptual understanding of content can limit teachers' learning opportunities, both in formal meeting opportunities like teacher workgroups as well as informal opportunities like advice networks.

The data in this study are now a decade old, yet the Era of Accountability is hardly over. The 2015 passage of Every Student Succeeds Act (ESSA) took away the one-size-fits-all model of testing from No Child Left Behind (NCLB), and allows states to determine their how they define and intervene in their poorest performing schools. States are still required to annually test students in grades 3 and 8 in reading and mathematics, and once in high school, and they must report disaggregated student data (https://www.ed.gov/essa). One significant difference between ESSA and NCLB is that school reports must now incorporate at least one non-academic indicator in addition to standardized test scores. While ESSA has the potential to shift national and local conversations away from a strict test-based regime, scholars are not hopeful. Mathis and Trujillo (2016) wrote in their analysis of the act, "In order for ESSA to achieve the kind of significant, equity-minded improvements that its original proponents imagined, state-level policymakers…will need to adopt a set of driving

principles and aims for schools that have been nearly absent from the discourse on and practice of school reform for the past thirty years…This is a herculean task" (p. 7). In combination with the pressures from the CCSS and other similar standards, however, the possibility of states taking on this herculean task is on the horizon.

In the context of a high-stakes accountability system in which easily measured student achievement gains are incentivized over the more complex and longer-term process of instructional improvement, the school leaders and teachers' focus on covering content is understandable. Our findings illustrate that an easily-measured approach had broad negative impacts on the academic rigor of the interactions among the mathematics department as a collective. Instead, we argue that school leaders should leverage and build conceptual expertise so that students are able to both be successful on tests and develop conceptual understandings of mathematics that are linked to procedural fluency. This aligns with Darling-Hammond et al.'s (2016) set of suggested pathways towards an era of "New Accountability" that includes multiple measures of student success that can be used within a continuous improvement model. Below, we delineate implications of our findings for both teachers and school leaders.

For Teachers and Teacher Leaders: We argue that the way in which teachers talked about mathematics in their workgroup conversations mattered. While their initial approaches (in 2008-2009) to talking about concepts may have helped students develop intuition about underlying mathematical concepts, it was likely insufficient to help students know how to flexibly apply mathematical procedures on standardized tests. For example, while students may have had better understanding of the concept of volume by thinking about how many file cabinets would it take to fill a room, unless these ideas were strategically investigated to reveal underlying patterns and relationships that lead to

formulas for computing volumes of common solids, it may be that students were unable to apply the knowledge from this activity to other mathematical tasks and problems about volume that appeared on state tests. As such, we argue that reforms need to focus on supports that build teacher capacity to successfully teach ambitious mathematics. Teacher workgroups are an ideal space for this to happen (Horn & Little, 2010). It is likely that the instructional coach and these teacher workgroups needed the support of an expert other (Brown, Collins, & Duguid, 1989; Vygotsky, 1978) to engender their own professional learning about mathematics and pedagogical content knowledge. There is ample research on teacher professional development (e.g., Borko, 2004), and calls for research on professional development for coaches (Woulfin & Rigby, 2017). Districts and school leaders are tasked to coordinate and provide these kinds of resources.

For School and District Leaders: School leader press can shift teachers' attention. While school leaders strategically use their positional power to shape the nature of instruction and policy implementation (Coburn, 2006), they may not be aware of how their press has broader impacts on teacher learning opportunities. Principals have complex jobs that entail giving their attention to multiple constituents and pressures, including teachers, parents, students, teachers' unions, central office leadership, and policies from multiple places in the institutional environment (Rigby, 2014). In the immediate, it must be the role of the central office to support principals in their work to make sense of these multiple and often conflicting messages. Further, district central offices need to provide aligned professional development for principals (and assistant principals) as well as to coaches and teachers, so that they are able to either a) give substantive support in implementation of discipline-specific instructional reforms (if they have deep content knowledge) or b) press for ambitious practices (if they don't have deep content knowledge).

In conclusion, this study reveals the complexity of two common supports for teacher learning, and thereby school improvement: provision of time for teacher collaboration and school leader press. While often implemented in an (indirect) effort to increase student achievement, the analyses of both the formal opportunities to learn in workgroups and the informal opportunities through advice networks illustrate the ways in which the structures themselves are not sufficient. Instead, we must consider the necessity of increased expertise in pedagogy and content across multiple functions in schools, including instructional coaching and school leadership.

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Appendix

Comparison between Creekside and the District on measures of teacher expertise

	2009	2010	2011
Years of experience			
Creekside	12.44	11.07	12.29
District	6.72	6.95	6.51
IQA Score			
Creekside	2.17	1.86	2.25
District	2.28	2.07	2.27
MKT Score			
Creekside	-0.10	-0.04	0.23
District	-0.15	-0.21	-0.20