Infrastructure Redesign and Instructional Reform in Mathematics: Formal Structure and the Practice of Teacher Leadership

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Abstract

This article examines one school district's efforts to improve elementary mathematics instruction through transforming its organizational infrastructure to support teacher leadership. Using social network surveys and interview data from 12 elementary schools, we explore how the district designed its infrastructure to influence teacher leadership practice in general and in mathematics in particular. We then consider how these formal structures influenced practice by examining changes in the mathematics instructional advice- and information-seeking behaviors among school staff. Our analysis revealed that the district undertook a purposeful selection process for teacher leaders in mathematics that facilitated the integration of new formal structures into the existing infrastructure. These new structures enabled formal teacher leaders to emerge as central actors and influential brokers of advice and information about mathematics. Additionally, the new structures put in place to support formal teacher leadership did not undermine the emergence of informal teacher leadership within schools.

National and state educational policies press for improvements in student performance through uniform standards and high stakes accountability, as measured by standardized tests. Still, local school systems are left to figure out how to create conditions that improve achievement, and many respond by working to support changes in teachers' instructional practice (Garet et al., 2001). Districts employ various mechanisms in these efforts, from the provision of professional development (e.g., Corcoran, Shields, & Zucker, 1998), the adoption of new curricula (e.g., Ball & Cohen, 1996), the use of teacher evaluation systems (e.g., Figlio & Kenny, 2005), and the implementation of instructional coaching (e.g., Mangin, 2009). Much of the available literature dwells on whether and sometimes why such mechanisms improve instruction or achievement; yet, these mechanisms are rarely deployed on their own. Rather, they are inserted into an existing infrastructure or are part of a broader effort to fundamentally redesign that infrastructure (Datnow, 2005; Fullan, 2000; Leithwood, Jantzi, & Mascall, 2002; Levin, 2009). Often, efforts to redesign the infrastructure work in changing instructional practice to the extent to which they transform practice in schools more broadly.

This article focuses on one district's efforts to improve elementary mathematics instruction through transforming its organizational infrastructure to support teacher leadership. Theoretically, investing in teachers as leaders allows teachers to take on responsibility for school wide instructional improvement (Lieberman & Miller, 1999, 2011; Lieberman, Saxl, & Miles, 1988), thereby resulting in changes to teachers' practices both inside and outside the classroom. Indeed, research increasingly recognizes the need to attend to sources of leadership outside of the principal (Camburn, Rowan, & Taylor, 2003; Spillane, 2006). Although teacher leadership has been advanced as a critical component of reform efforts (Smylie, Conley, & Marks, 2002), much of the literature focuses on the development and experiences of teacher leaders as individuals

(York-Barr & Duke, 2004). In many ways, however, teacher leadership practice must be understood in relation to the infrastructure that districts and schools put in place to support it (Fullan, 2001). The present study is thus a theory-building effort to understand the relationship between infrastructure and the practice of teacher leadership.

Based on prior empirical work, our study is premised on the assumption that the school subject matters when it comes to leadership writ large and teacher leadership in particular. Given that the majority of teacher leadership studies focus on literacy or English language arts (Coburn & Russell, 2008 is an exception), we investigated relations infrastructure redesign and teacher leadership practice in mathematics. Using social network surveys and interview data from 12 elementary schools in one school district, we first examined how the district designed the formal infrastructure to influence teacher leadership practice in general and in mathematics in particular. We then considered how these formal structures influenced practice by examining changes in the mathematics instructional advice- and information-seeking behaviors among school staff. We focused on advice- and information-seeking patterns because advice and information are considered fundamental building blocks for developing knowledge, a critical ingredient for improving instruction in schools (Darling-Hammond et al., 2009; Elmore, 1996; Hill, 2004).

We begin by examining the relationship between infrastructure and school practice and anchoring our work in the literature on teacher leadership. Next, we describe our research approach to this longitudinal mixed methods study. We then report our findings. Our analysis revealed that the district undertook a purposeful selection process for teacher leaders in mathematics that facilitated the integration of new formal structures into the existing infrastructure. These new structures enabled formal teacher leaders to emerge as central actors and influential brokers of advice and information about mathematics in their schools. Finally, the new structures for teacher leadership in mathematics did not appear to undermine the existence of informal teacher leadership, and they worked in tandem with the existing infrastructure.

Anchoring the Work: Infrastructure, School Practice, and Teacher Leadership

An increasingly popular reform approach involves schools and districts purchasing off-the-shelf ‘proven’ models to improve instruction (Nehring, 2009). Such a model, for example, is promoted by the U.S. Department of Education’s *What Works Clearinghouse*. While this approach has its merits, it is unlikely on its own to be sufficient. Even if local school systems could rely on such remedies to improve instruction, they still must figure out what combination of remedies to select to address their needs and then tailor these remedies to work in their particular context (Datnow, 2005; Elmore, 1996; Hargreaves & Fink, 2000; Peurach, 2011). As a result, rather than relying solely on off-the-shelf models, local school systems must engage in designing and redesigning infrastructure to support instructional improvement.

Infrastructure, or the formal structures that shape practice, is essential to understanding practice in organizations; indeed, “building formalities that work” has been and continues to be a central challenge in organizations (Stinchcombe, 2001, p. 2), and K-12 schools are no exception. Efforts to redesign public schools over a century or so indicate that formal structures are often just rituals that fail to influence practice (Meyer & Rowan, 1977) or that formal structures get corrupted, intentionally or unintentionally, resulting in little influence on practice. For example, much educational research highlights how policies, as formal structures, are negotiated and at times rejected by teachers at the classroom level (e.g., Coburn, 2006; Spillane & Jennings, 1997). As such, attention to macro-level forces, or the infrastructure and how it is designed, and to micro-level forces, or how structures are taken up in practice, is essential (Berman &

McLaughlin, 1974; Corbett, Dawson, & Firestone, 1984; Fullan, 1999). We thus attend explicitly to formal structures and their relationship with district and school practice.

Teacher Leadership: Infrastructure and Practice

While often not directly examined or addressed, research has revealed various structures that can support the development of teacher leadership. The adoption of instructional coaches is highlighted most prominently in the literature as a key mechanism for cultivating full- or- part-time teacher leaders, whose primary roles are to support instructional improvement or reform efforts (e.g., Camburn, 2010; Coburn, Choi, & Mata, 2010; Coburn & Russell, 2008; Firestone & Martinez, 2007; Mangin, 2009). These formal teacher leadership positions are frequently implemented as the result of a new policy (Atteberry & Bryk, 2010; Camburn et al., 2003; Matsumura, Garnier, & Resnick, 2010), such as Reading First (Coburn & Woulfin, 2012; Walpole, McKenna, Uribe-Zarain, & Lamitina, 2010), or to support the adoption of curricular resources (Coburn et al., 2010; Coburn & Russell, 2008). Although the implementation of these formally designated teacher leaders brings a new structure to districts and schools, these structural aspects are often overlooked. Several studies focus at the individual coach level or on coach-teacher interactions, examining coaches' knowledge development or the types of support that coaches provide and how these factors affect reform implementation (Antsey & Clark, 2010; Coburn & Woulfin, 2012; Firestone & Martinez, 2007; Mangin, 2009; Walpole et al., 2010). While these studies offer important insights into coaches' development and their influence on teachers, they do not attend explicitly to the broader structures that support coaching.

The few studies that have paid attention to district infrastructure for teacher leadership and its relationship to school practice focus on how newly-assigned instructional coaches influence the nature and quality of staff interactions (Atteberry & Bryk, 2010; Coburn et al., 2010; Coburn & Russell, 2008; Stein & Coburn, 2008). Some of this research has shown that, after completing training and taking on new positions, coaches can emerge as central actors in their schools' social networks (Atteberry & Bryk, 2010) thereby increasing teachers' access to information and expertise (Coburn & Russell, 2008). These studies emphasize the coach position as a formal structure that influences practice; however, attention to how this structure fits into existing reforms or structures at the school or district levels is limited. These relationships are important, as one cross-district study revealed that the implementation of a coaching initiative alone did not influence staff interactions; careful attention to the selection and training of coaches at the district level and to routines of interaction within schools were also critical (Coburn & Russell, 2008). The present study adds to this work by exploring how new formal structures that support teacher leaders – coaches as well as other types of teacher leaders – are situated within a larger organizational infrastructure. In doing so, we directly examine the relationships between new and existing infrastructures and the practice of teacher leadership.

School and District Practice: Advice and Information Networks

Our attention to teacher leadership, both coaching and other forms, is premised on the notion that school or administrative practice is not just about the school principal, or even the school leader plus a few key individuals. In considering practice, it is important to examine who co-performs that practice and how expertise may be in between or "stretched over" two or more people – the basis for distributed leadership (Spillane, 2006). This approach requires going beyond notions of practice as individual action to practice as embedded in interactions. We thus approach school practice as social; that is, practice is *the medium for* interactions. We uncover practice by examining teachers' intra-school social networks, which help to reveal the on-the-job interactions associated with the transfer of advice and information.

Advice and information are essential to the development of knowledge, and knowledge development is considered crucial to instructional improvement (Darling-Hammond et al., 2009; Elmore, 1996; Hill, 2004). While formal learning opportunities have taken center stage for policymakers, teachers also develop new knowledge through interactions with colleagues on the job. This on-the-job learning occurs when organizational members ask questions and get information, observe colleagues, and give and receive feedback (Eraut & Hirsh, 2007; Frank, Zhao, & Borman, 2004; Little, 1993; Smylie, 1995). Teachers' advice and information networks, then, are important to the ongoing development of knowledge about instruction. We use these networks to examine the social or informal organization in districts and schools, which, in this case, is centered on teacher leadership practice. In doing so, we attend to both the informal and formal organizational structures and the relationships between them, as both are important components of the school reform process (Daly, 2010; Glazer & Peurach, 2012).

Research Approach

To examine the relationship between infrastructure and school practice, we use data collected over two years in one mid-sized suburban school district in the Midwestern United States, which we refer to as Auburn Park Public Schools (APPS). Drawing on social network survey data gathered in spring 2010 and spring 2011 from all of Auburn Park's elementary schools, we examined changes in advice- and information-seeking behaviors between the two years of the study before and after the district redesign of its infrastructure for teacher leadership in mathematics. We also use interview data collected between 2010 and 2012 from staff in five elementary schools to examine issues emerging from the social network data and to better understand what informs teachers' decisions to seek out others for advice about math. We also use interviews with two central office staff members to further examine the district's infrastructure design and redesign efforts related to teacher leadership. Drawing on the social network data and interviews allowed us to "zoom" in and out between the district, school, and individual levels and carefully examine the associations between infrastructure and practice.

Data

In the 2010-11 school year, Auburn Park served 5,630 students within its 14 elementary schools. The schools varied with respect to socioeconomic status, where six schools qualified for Title I funding, while the remaining eight were located in relatively affluent communities (see Table 1). Although all schools served predominantly white student populations, four schools served more than 10 percent African American and/or Latina/o students.

[Insert Table 1 about here.]

Social Network Surveys

In spring 2010 and spring 2011, APPS's teaching and administrative staff was asked to complete a survey that focused on various aspects of the school as an organization, including school culture (i.e., normative structure) and their advice- and information-seeking behaviors in mathematics and English language arts. To examine staff interactions, or social networks, high response rates are necessary to ensure reliable data, ideally as high as 80 percent. Two schools had below 40 percent response rates in 2009-10 and were thus excluded from the present analysis. Of the remaining 12 schools, 311 staff members completed the survey in 2009-10, and 337 in 2010-11, for an overall response rate of 89 and 96 percent, respectively. Individual school response rates ranged from 82 to 100 percent in 2009-10 and from 93 to 100 percent in 2010-11.

Survey Measures

To examine school practice in mathematics and associated changes over time, we focused on school staff interactions as measured using the social network survey items. Data on math advice and information networks were collected using a series of survey items collected via Snap Surveys, an online tool for collecting survey data. First, respondents were asked: *During this school year, to whom have you turned to for advice and/or information about curriculum, teaching, and student learning?* Respondents could nominate up to 12 individuals by entering first and last names. Next, the program generated a list of these individuals and asked the respondent to indicate the content area related to the advice and/or information he or she sought from each person listed: mathematics, reading/English language arts, and other. For our purposes, we focused only on those individuals to whom respondents turned to for advice and/or information about mathematics. In addition to generating sociograms, or visual displays of staff interactions, we used these data to calculate three network centrality measures.

Degree centrality is a measure of the prominence of an actor based on the assumption that those actors who are better connected than others are more central in the network. Degree centrality is simply a count of an actor's total number of relations; yet, we can break degree centrality into *in-degree centrality* and *out-degree centrality*. An actor's in-degree centrality refers to the number of people who sought out that actor for advice or information, whereas an actor's out-degree refers to the number of people that actor sought out for advice or information.

Betweenness centrality measures the extent to which an actor links two other actors in the network; interactions between any two actors in a network may depend on a third actor who links them together, making the linking actor more prominent in the network. Betweenness is thus a measure of brokering, or the extent to which an actor brokers information between other actors. Because betweenness measures the likelihood that a path from any two actors takes a specific path, we assume that the shortest path will be taken with equal weight of all lines.

We measured the betweenness of actor i by calculating the total number of geodesics (paths) between all other actors that include *i*. We removed all of those that connect any two actors *j* and *k* that are longer than the shortest path, and then count all of those which include *i*. We divided this by the number of paths using *i,* as follows:

$$C_B(n_i) = \frac{\sum_{j<k} g_{jk}(n_i)}{g_{jk}}$$

To examine the information- and advice-seeking behaviors among school staff and to examine the roles teacher leaders play in their school's mathematics advice and information networks, we compared average centrality measures for teacher leaders and non-teacher leaders and tested these differences for significance using independent t-tests. We also compared changes in these measures between the two years of the study using paired sample t-tests. Due to the dependence of variables used in social network analysis, we used UCINET's (Borgatti, Everett, & Freeman, 2002) node-level t-test to generate significance levels based on permutations of the dependent vector (Hanneman & Riddle, 2005).

<u>District and School Staff Interviews</u>

As a follow-up to the surveys, a subsample of schools, teachers, and administrators were selected to participate in semi-structured interviews. Five schools (as noted in Table 1) were selected to represent a range of organizational structures, from schools with math coaches to those with no designated teacher leaders in math. We interviewed each principal and between four to seven teachers at each school for a total of 33 interviews. Teachers were selected based on their survey responses to ensure that teachers across grade levels were included, as well as teachers who were well integrated in their schools' math networks and those who were isolated. In addition, interviews were conducted with two central office staff members, Georgia, the Director of Elementary Curriculum, and William, the Elementary Instructional Facilitator.

Interview questions for school staff elicited information about how and why they interacted with particular individuals about math instruction. In contrast, interview questions for central office staff focused on the district infrastructure and redesign efforts related to teacher leadership in mathematics. All interviews last between 40-50 minutes and were audio recorded, transcribed, and imported to NVivo 9 for coding and analysis. In the first round of coding, the interviews were open coded (Miles & Huberman, 1994), and several salient themes and subthemes emerged. For example, a theme that emerged around why staff members interacted about mathematics was related to organizational routines. Other codes related to the formal structure included school- and district-level professional development, yet social connections and proximity also emerged as key reasons for staff members to interact about math. Additionally, expertise emerged as a key reason school staff sought out others for advice or information about, which could be categorized in several ways: formal position (e.g., coach or administrator), specialized training, as well as general knowledge or interest. Many of these themes align with prior research (Supovitz, 2008), with the exception of organizational routines and specialized training, which emerged as new themes from our data.

Using these codes, two researchers conducted a second round of coding. Through this process, the coding scheme was refined and codes were added, including subcodes under organizational routines related to curriculum and planning and new codes related to general sharing and collaboration about math instruction. The researchers used the refined coding scheme to code one-third of the interviews and establish inter-rater reliability. The process of establishing inter-rater reliability included coding one interview and meeting to discuss commonalties and discrepancies. Afterward, the researchers recoded the interview and met again to discuss differences. Once Kappa coefficients of .85 or greater were established for the first interview, researchers coded four more interviews. Kappa coefficients for this set of interviews ranged from .72 to .99, and, as such, one researcher coded the remaining interviews.

Study Limitations

In this exploratory theory-building study, we make no attempt to generalize beyond the schools or district under study. As such, our findings are limited to the district context explored here, although we believe the findings useful to similar districts undergoing infrastructure redesign efforts. Our study also examines changes in school practice over just two years, limiting the extent to which causal claims can be made about the relationship between teacher leadership and changes in school practice. Moreover, the new formal structures examined in this study were implemented at the same time that the district adopted new curriculum resources in mathematics. Although the infrastructure redesign was not undertaken as a result of the resource change – as has been the case in other studies (e.g., Coburn & Russell, 2008; Stein & Coburn, 2008; Walpole et al., 2010) – we cannot know how this change influenced advice- and information-seeking behavior independent of the new teacher leadership structures.

Findings

We begin our account by describing the district's efforts to design and redesign its infrastructure for teacher leadership in mathematics, including two core aspects implemented between 2009 and 2011. We then explore if and how these structures were associated with changes in school practice by examining trends in the advice- and information-seeking behaviors among school staff. To illustrate the broad trends revealed in the social network data, we draw upon two teacher leader cases, John at Chavez Elementary and Emily at Bryant Elementary.

(Re)Designing Infrastructure to Support Improvement in Mathematics Instruction

Local efforts to redesign infrastructure do not take place in a vacuum; new organizational structures are grafted on top of existing structures. While scholars like to ‘control for’ these pre-existing conditions by randomly assigning subjects to treatments, research on schools often cannot do this. From a policy or practice perspective, rather than something that needs to be controlled for, the existing infrastructure is something to work with or that might work against design efforts (Datnow, 2005; Peurach & Glazer, 2011). Understanding how new designs coalesce or clash with the existing infrastructure is critical to the reform process. Examining APPS’s efforts to develop teacher leadership helps us understand this redesign work.

Existing Infrastructure for Teacher Leadership

Local school leaders face several challenges with respect to organizing instruction. One key challenge concerns the vertical and horizontal alignment of the curriculum; another involves improving staff capacity. District officials and school principals are hard pressed to accomplish these tasks single handedly. In APPS, organizational routines helped to distribute leadership and to foster teacher leadership within core subject areas, including Professional Learning Communities (PLCs) at the school level and toolboxes and arrays at the district level. We define organizational routines as “a repetitive, recognizable pattern of interdependent actions, involving multiple actors” (Feldman & Pentland, 2003, p. 95); these routines must be repeated over time, recognized by those involved, and include two or more staff members.

Between 2009 and 2011, APPS introduced two mechanisms to support teacher leadership in mathematics – a knowledge development effort and a coaching initiative. These were designed to promote instructional coherence around ambitious standards for elementary math education. The district’s ability to foster this coherence was contingent on how these structures were grafted onto or integrated into the existing infrastructure. We thus begin by describing the district's existing organizational routines that focused on developing teacher leadership.

School-Level Infrastructure: Professional Learning Communities

At the school level, grade-level teams participated in PLCs, an organizational routine that involved teachers meeting weekly to discuss instructional issues. Each meeting centered on a topic, from examining student data to lesson planning:

> Our PLC meetings were structured where every week was set up by a topic. Each month we had four topics that you would hit. There's one PLC a month dedicated to student concerns. We always had one that was data, looking at different student data, whether it was guided reading levels or math data. There was always one meeting that was unit or lesson planning. Then there was a flex week where you could get done whatever else you wanted. (William [5th grade, Kingsley], personal communication, February 1, 2012)

In addition to grade-level teachers, special education teachers were also invited to PLCs, as well as the literacy coach and, on occasion, the principal. Even so, PLCs were not led by formal school leaders, as they were designed by the district to focus on teachers' work together: "Teachers very much lead their own grade level meetings. In the beginning, we were very tightly managed, that 'I want you to talk about kids at this time,' 'I want double scoring at this meeting,' and so it was more tightly managed in the beginning [but shifted] to more loosely [managed] as teachers started taking control of their own groups" (Georgia [APPS Director of Elementary Curriculum], personal communication, February 2, 2012). As PLCs became embedded in school infrastructure, teachers took over organizing and leading PLCs from district and school leaders.

In fact, PLC leadership responsibilities were often shared among teachers: "I think in doing the PLC's it [leadership] kind of builds, so everybody's kind of working together so that there isn't one specific leader" (Laura [3rd grade, Kingsley], personal communication, February 1, 2012). At times, however, leaders emerged depending on teachers' levels of expertise: "I wouldn't say there is leader, if we really have a leader per se. I don't know if it's Katie [another 2nd grade teacher] or me. I'm not sure which one it is. Maybe we share it. I'm thinking that's what we do. She does what she does well; I do what I do well" (Jessica [2nd grade, Bryant], personal communication, February 1, 2012). Though there was not a designated leader, teachers drew upon each other's expertise to distribute leadership across PLC teams.

District-Level Infrastructure: Toolboxes and Arrays

At the district level, teacher leadership was fostered through curriculum committees, or "toolboxes," and through an array structure that grouped similar schools for professional development activities. First, the toolbox routine brought teachers from different schools together at the central office to share expertise and resources within each core subject area, including English language arts, mathematics, science, and social studies. Each toolbox had between 12 and 30 members and met a few times each year. Toolbox members, all of whom were teachers, were responsible for writing the curriculum, aligning that curriculum with state standards, selecting the resources that would be used to teach the curriculum, and writing summative assessments to go along with the curriculum and resources. The district used this approach to bring coherence to the system between curriculum, assessments, and instruction, but also to align these components to state and national standards (Wiggins &McTighe, 2005).

The "power" in the toolboxes, according to Georgia, was in building teachers' capacity to develop curriculum and make decisions that would impact other teachers: "The power I think in our toolboxes is because we build capacity in our teachers and those leaders, they make good, solid decisions when it comes to selecting a curriculum for the district that's not necessarily the easiest curriculum, but it's the right curriculum" (personal communication, February 2, 2012). This shared leadership allowed teachers to serve as district decision makers. Georgia also noted that toolbox members were the district's "change agents," responsible for taking information back to their schools and helping teachers utilize that information in the classroom.

Among school staff, teachers' toolbox participation was an indicator of content expertise: "If I had a question [about math] I'd probably go to the two toolbox members because they've both been on that math toolbox, so you know they have that good math background knowledge" (Becky [4th grade, Chamberlain], personal communication, February 2, 2012). Additionally, math toolbox members served as good resources for answering curriculum-based questions, as noted by Katie, a 6th grade teacher at Chavez: "I talk to my teammate a lot, the other 6th grade teacher, because she is on the math toolbox. Since those are discussions that she has more often as far as the curriculum – what it is and why they chose it and where it's going – that's who I go to because she's kind of the lifeline to the curriculum department at central office" (personal communication, February 1, 2012). The role of toolbox members as "lifelines" to the district office indicates that the toolbox structure enabled connections between different units of the school system. Thus, toolbox membership not only signified teachers' math content knowledge, but also their capacity to serve as information conduits between the school and the district.

The selection process for toolbox participation changed over time. At first, principals nominated individuals for participation who they viewed as strong teachers and instructional leaders. District administrators selected at least two teachers from every grade level and selected teachers from each of the district's 14 elementary schools. This process allowed for vertical alignment of the curriculum, and it ensured that similar content was taught across schools (Georgia, personal communication, May 16, 2012). However, in mathematics, principals and administrators felt that some schools did not have teachers with both content knowledge and leadership capacity; thus, only 9 of the 14 elementary schools were represented on the math toolbox. While this meant that only highly skilled teachers were included, it also meant that some schools were left out of this organizational routine.

The second district-level organizational routine, arrays, facilitated relationships between similar schools. The central office arranged schools into four arrays based on students' socioeconomic status, where, for example, Title I schools were assigned to the same array. The district used arrays to bring teachers together for professional development, requiring meetings three times per year. In many ways, array meetings leveraged the teacher leadership developed in toolboxes, as toolbox members were often asked to organize and lead meetings around information they acquired through their work on the toolbox. Georgia viewed the arrays as an opportunity to develop teacher leaders in mathematics, especially for schools without math toolbox members: "In math, we have to make sure that we do our professional development through arrays. Some buildings don't have toolbox people in math, so they work on professional development in the context of arrays….We have to bring everybody up. And through those arrays that's a tool that we can use to build teacher's capacity" (personal communication, February 2, 2012). Thus, in addition to fostering ties between teachers in different schools, arrays provided access to instructional leaders (i.e., toolbox members) and to curricular information.

<u>New Infrastructure Focused on Teacher Leadership in Mathematics</u>

To understand the district's infrastructure redesign efforts for teacher leadership in math, it is important to consider how APPS's new structures were layered onto or integrated into the existing school- and district-level organizational routines.

Teacher Knowledge Development Effort

In 2009, APPS partnered with a university to implement a mathematics professional development program, Fundamental Math (FM). Fundamental Math included two aspects – a K-3 Math Specialist certification program and support for participants when they returned to their schools as teachers or math coaches. The 18-month program focused on deepening teachers' knowledge and understanding of core math topics and mathematics teaching and learning. The topics covered were those addressed in the elementary mathematics curriculum and thus developed teachers' knowledge of the specific concepts necessary to support children's learning and development. Courses featured the mathematical ideas underlying the National Council of Teachers of Mathematics (NCTM) standards and offered teachers accessible math experiences as well as pedagogy courses designed to support the design and implementation of rich lessons across the curriculum. To support participants as they returned to their schools, courses also focused on instructional leadership and how to build math communities of practice.

APPS administrators worked with school principals to select teachers for participation. Each principal nominated one teacher who they felt was a math content expert and had potential to become an instructional leader, and possibly a math coach. District administrators, including Georgia, compared this information to the math toolbox list in an attempt to select teachers who were also district curriculum leaders. The university allotted nine spots for APPS; thus, district administrators selected nine teachers from different elementary schools, eight of whom also served on the math toolbox. By strategically selecting teachers to participate in Fundamental Math who were also involved in the toolbox, the new structure integrated into the existing teacher leadership infrastructure and was not a disconnected "add-on" to current initiatives.

Mathematics Coaching Initiative

The second aspect of APPS's efforts to redesign its infrastructure involved the creation of formal teacher leader positions. At the beginning of the 2010-11 school year, with funding from the university partner, APPS instituted math coaches at three elementary schools. Instructional coaches were not new to APPS, as every elementary building already had a full-time literacy coach. In fact, the district's success with literacy coaches motivated their decision to experiment with math coaches: "We saw the impact literacy coaches had on reading and writing instruction, so we knew that having math people coaching would have an impact on math. And we had the luxury that we had this grant from the university that could help do that….Then that commitment would be would we feel like it's effective enough to continue it and to pay for it on our own?" (Kelly [principal, Chamberlain], personal communication, February 2, 2012). Our social network analysis supported the claim that literacy coaches influenced school practice, as coaches were prominent actors in every school's English language arts (ELA) advice and information network. In contrast, math networks often lacked such central actors prior to the math coach initiative.

The three math coaches were formally full-time teachers at their schools. Two coaches took on full-time leadership positions, while the other was a half-time coach and half-time math teacher. The coaches were selected by district administrators because they were known as strong math teachers, passionate about mathematics, and well-respected by colleagues. They were also already known in the district as teacher leaders in math due to their membership on the math toolbox. Moreover, they were enrolled in the FM program and, as such, were completing additional training in math instruction and leadership. In this way, coach selection supported both the existing infrastructure and the other newly implemented formal structure.

Overall, there was substantial overlap between the two new formal structures and the district's existing infrastructure for teacher leadership. However, the alignment between these structures was not seamless, as there were several math toolbox members who were neither coaches nor FM participants. Additionally, five elementary schools were left out of the new structures altogether, as they did not have teachers selected to participate in Fundamental Math or to serve as math coaches. In the next section, we examine how these new formal structures relate to school practice in mathematics across all of the district's schools.

Teacher Leadership Infrastructure and School Staff Interactions in Mathematics

It is one thing to design and redesign formal structures, but whether and how these structures influence practice is another matter. Specifically, we must examine relations between the formal structures designed by APPS to promote teacher leadership and practice in mathematics inside schools. It is tempting, especially in the current political climate, to ask whether APPS's investment in structures to support teacher leadership worked. That is, were new formal structures to support teacher leadership efficacious in improving student learning in mathematics? These questions are indeed critical, but such changes take time and are dependent on changes in teachers' instructional practice and on teachers' will and opportunities to learn.

Thus, we believe some questions are equally important and must be answered first if we are to understand whether and how the district's redesign efforts actually worked to transform practice. For example, how does investing in the mathematics disciplinary and pedagogical knowledge of selected teachers and in coach positions influence advice and information providing and receiving behaviors? How do these new structures work with or against existing organizational routines to shape school practice? Because advice and information are precursors to knowledge development – which in turn shapes instructional practice and influences student achievement – we focus on these intermediate changes in practice.

Teacher Leaders as Central Actors and Brokers in Math Advice and Information Networks

In this section, we show how APPS's design efforts influenced teachers' advice- and information-seeking behaviors about math instruction. We begin by examining FM participants' roles in their schools' math advice networks, then explore the roles that math coaches played.

Specialized Training: Fundamental Math

To begin, participation in FM influenced whether or not teachers were sought out for advice or information about math. Specifically, the average in-degree of the nine FM participants increased significantly ($p<.05$), from 5.0 in 2009-10 to 9.4 in 2010-11, indicating that an average of four additional staff members nominated these individuals after they were enrolled in the certification program (see Table 3). Conversely, the average in-degree of non-participants remained constant. While the three math coaches were also FM participants, a significant increase in average in-degree remained upon removing the coaches from the FM participant sample (4.33 in 2009-10 to 6.00 in 2010-11; $p<.05$). This finding indicates that the specialized training in itself was influential in informing teachers' advice-seeking behaviors.

[Insert Table 2 and Table 3 about here.]

An examination of John's network (see Table 2 and Figure 1) illustrates this trend. John is a 2nd grade teacher at Chavez Elementary and an FM participant (non-coach). In 2009-10, five teachers nominated John as someone they went to for advice or information about math instruction; in 2010-11, eight teachers nominated him (shown as arrows pointing toward John). John thus became more central in the Chavez math network after he began the training program.

[Insert Figure 1 about here.]

It is important to note that the average in-degree for FM participants was significantly higher ($p<.001$) than the average in-degree for other teachers in both years of the study. This finding suggests that the district's strategic selection process allowed teachers who were already key advice providers at their school sites to participate in Fundamental Math. Even so, that the average in-degree for other teachers did not increase indicates that the district's investment in selected teachers' knowledge development significantly influenced the extent to which these teachers were sought out for math advice or information. Thus, FM participants' increased centrality was not merely the result of an overall shift in advice-seeking behavior in the district.

Teachers' accounts supported these findings. Karen, a 1st grade teacher at Chavez, discussed the importance of the FM training for her decision to seek out John for advice: "He's kind of become kind of a math person to see because *he's taken this extra training that nobody else in the building has done*, and I know that he's interested in math, so he's just one that I've gone to that I know focuses very heavily on math" [emphasis added] (personal communication, January 11, 2011). Because John was the only teacher to participate in the specialized training, Karen viewed him as "a math person," someone who had particular knowledge and could offer advice or information in that subject area. Similarly, John developed a relationship with his principal, Mary Beth, after becoming part of FM. While John is not connected to Mary Beth in 2009-10, Mary Beth is part of his network in 2010-11 (see Figure 1). Indeed, Mary Beth described how John's involvement in FM changed his relationships with her and other teachers:

> It's probably just been in the last year [since Fundamental Math started] that I've seen from him the strong interest in leadership in math. I speak regularly with him about math instruction and about staff development and what we need to be doing in the building. He's very inspired by the program, and we talk a lot about the things he observes. He's never critical of teachers, and I do think that they are aware of that and go to him easily, and then he can be a sounding board to me. (personal communication, January 11, 2011).

After John enrolled in Fundamental Math, he began to serve as a key advisor and "sounding board" to Mary Beth about math instruction at Chavez. At the same time, he served as an important source of information and maintained non-evaluative relationships with other teachers. Similarly, 14 of the 20 staff members we interviewed mentioned participation in FM as a reason they sought out a colleague for advice about math. For example, Kelly, the principal at Bryant, described going to Mary, the FM participant at her school, for advice: "Mary's been through a lot of the training; she's had the desire and the passion for math. I go to her [for advice about math] first," (personal communication, February 1, 2012), and Andrea, a 3rd grade teacher at Ashton, spoke about Carmen, the FM participant at her school: "I respect her [Carmen's] opinion, I think she knows a lot about math, and she's learning more all the time. She's taking classes on the weekends and she's able to show me new things" (personal communication, January 11, 2011).

In addition to becoming more central actors in their school's math networks, FM participants also took on new brokering roles. We again turn to John to illustrate the relevance of this information brokering. Specifically, John brokered information about math instruction across more grade levels after he enrolled in Fundamental Math (see Figure 1). While he had ties to grades 1-3 and special education in 2009-10, he had connections with grades K-2, grade 4, grade 6, and special education in 2010-11. Moreover, John became a more influential broker, as he formed two additional closed triadic relationships in 2010-11. In closed triads, two actors who are tied to a third actor are also tied to each other, and these closed ties often have the greatest capacity for influence and are longer lasting than other ties (Krackhardt , 1998; Simmel, 1950).

We measured overall brokering for FM participants by examining changes in their average betweenness centrality. Our analysis revealed a shift from 32.4 in 2009-10 to a full 144.3 in 2010-11 (see Table 3). Although only marginally significant ($p<.10$), this change is substantial when compared to that of other teachers, whose average betweenness increased from just 10.9 to 24.8. Moreover, there was a significant difference in the average betweenness of FM participants and other teachers in 2010-11 ($p<.01$), but not in 2009-10, indicating that FM participants occupied more central brokering roles than other teachers after starting the training program. As above, this finding held even when excluding the three coaches from the FM participant group.

Indeed, FM participants attributed their increased brokering to the training: “I think that especially with being in Fundamental Math my confidence in my math ability and my math teaching has gotten a lot greater, and I’ve been able to bring a lot of that back and share with staff. I think that they’ve started to see that I’m willing to take that role, and I think that they kind of want that ” (John, personal communication, January 21, 2011). Thus, on top of marking FM participants as teachers with expertise, enrollment in FM increased their confidence and motivated them to share ideas, which in turn made teachers more willing to ask them for help.

Formal Position: Mathematics Coach

Among FM participants, the three individuals who were also coaches stood out as math teacher leaders at their schools and within the district. Within schools, the formal position was a signal for teachers that these individuals were go-to experts for advice and information about math, greatly increasing the extent to which coaches were sought out by colleagues. In 2009-10, the average in-degree centrality for math coaches was 6.3; in 2010-11, after assuming coach positions, their average in-degree increased significantly ($p<.01$) to 16.3. Thus, an average of 10 more teachers nominated coaches as individuals they sought out for advice about mathematics.

Like other FM participants, coaches had significantly higher in-degrees than other teachers in both years. This finding provides further evidence that the district selected teachers for participation in the new formal structures who were already viewed as informal leaders. Yet, the formal position in itself was influential in making the coaches more central in their schools' math networks and served as an explicit marker of expertise. When asked why she went to Mary, the math coach, for advice, Jessica, a 2nd grade teacher at Chamberlain, put it simply: "Because she's our math coach. She's supposed to know it" (personal communication, February 1, 2012).

The increase in advice-giving among coaches was evident in Emily's math network. While Emily, Bryant's math coach, had seven incoming ties in 2009-10, she had 16 such ties in 2010-11 (see Figure 2). Angie, a special education teacher at Bryant, described how Emily became the "go-to" person for advice about mathematics after assuming the formal role:

> [Emily] really wasn't our facilitator [last year] though, she was my co-worker, just a 3rd grade teacher. I mean, I knew she had a wealth of knowledge, I just wasn't in [her classroom] at the time when she was teaching math. But *now that she's moved into this math facilitator position*, that's different. She's been trained in math. And, she's gone to school for it [math training] and she's a great coach, she knows a lot about math and I just trust that she has a lot of, a wealth of knowledge on it; she's been studying it. She's the go-to person. [emphasis added] (personal communication, December 16, 2010)

Like Jessica, Angie noted that the formal position factored into her decision to seek Emily out for advice. Whereas she viewed Emily as "just a 3rd grade teacher," before she became the coach, she later saw Emily as the "go-to person" she trusted to ask questions about math. In Angie's view, however, it was not simply that Emily assumed a new coach position, as she explicitly pointed to Emily's new expertise when she noted "she's been trained in math…she's been studying it." For Angie, then, it was a combination of the new position coupled with Emily's new expertise in mathematics that was at play in her decision to seek her out for guidance.

[Insert Figure 2 about here.]

Not only do teachers seek coaches out for advice and information about mathematics instruction more often than other teachers and FM participants, but the *full-time* coaches also reported reaching out to more individuals for advice about math. The out-degree centralities of the full-time coaches increased by seven between the two years of the study, indicating that they each reached out to seven more individuals for advice about math after assuming the formal position (see Table 2). In contrast, the out-degree for the half-time coach decreased by three.

These differences between the full- and half-time coaches were likely related to the amount of time coaches were able to devote to seeking out others for advice about mathematics. Without any classroom responsibilities, full-time coaches could focus on supporting teachers: "I think [my interactions with teachers] changed [after becoming the coach] in a sense that I wasn't in a classroom, so now I have time to support them even more. I have time to be in their classrooms, to go to all their PLCs. So before it was that limited time, where it was just if we happen to catch each other, whereas now my availability is the biggest difference" (Mary, personal communication, February 1, 2012). As the full-time coach, Mary had more time to reach out to and interact with her colleagues in a variety of activities that supported their math instruction. On the other hand, Carmen, the half-time math coach at Ashton, had only mornings set aside for coaching. Since most teachers taught math in the afternoon, she did not have time to observe math instruction and instead spent most mornings waiting for teachers to come to her: "In the morning, this [my classroom] is my home base, so teachers would usually just come here" (personal communication, January 11, 2011). Thus, the school schedule and time allotted for coaching affected Carmen's ability to assume her coaching responsibilities.

The limitations Carmen experienced were also evident among the six FM participants who remained in the classroom during the 2010-11 school year. In general, these individuals did not experience the substantial positive shifts in out-degree that the full-time coaches did, where the average out-degree for FM participants increased by just 0.3, or less than one individual. John, for example, did not change his advice-seeking behavior between the two years of the study, as he continued to seek out just two other staff members for advice about math. As was the case for Carmen, this trend is likely related to the lack of time that FM participants had to reach out to other teachers, since they were assigned full-time to classrooms. These trends point to the importance of taking a holistic approach to infrastructure changes. That is, while a new formal position influences advice-seeking behavior, the ability of coaches to take advantage of their role depends on how they are situated in the overall school and district infrastructure.

In addition to increasing advice giving and seeking about mathematics, the full-time coaches emerged as central brokers of math information, both within their schools and between their schools and the central office. While the betweenness of the part-time coach decreased (see Table 2), Emily's betweenness increased from 18 to 185 and Mary's from 34 to 545. The importance of this increase is illustrated in changes to Emily's math network (see Figure 2). In 2009-10, Emily's interactions were primarily focused within the school, reaching to grades 3-4, 6, special education, and to the literacy coach; yet, Emily also interacted with Mary, her coaching counterpart who was a 3rd grade teacher at Chamberlain. In contrast, in 2010-11, Emily interacted with at least one teacher at every grade level K-6, as well as special education, the literacy coach, and the principal. In addition, she kept her tie to Mary and added four ties to the central office. Thus, like John, Emily brokered information about math across more grade levels and between teachers and the principal, but she also served as a broker between her school and the district office. These increased tie spans are important for developing new knowledge and facilitating innovation (Granovetter, 1983; Tsai, 2001), suggesting that the formal position enhanced Emily's knowledge as well as the knowledge of those with whom she interacted. Indeed, Emily described how her responsibilities facilitated brokering:

> Well, my involvement at the school and district changed because of my position this year as a math coach. I'm constantly in, trying to be in math classes to observe, I'm coaching, I'm talking to teachers, I have district meetings that I have to be at, I work with the other math coach in her building, we get together and we provide staff developments we work a lot together, those kinds of things. (personal communication, December 16, 2010)

Emily's reach both inside and outside the school indicates that math information was spread throughout the school and that there was some level of coherence between the district and school. Moreover, Emily forged 17 new close triads in 2010-11, suggesting that she became a highly influential information broker. These relationships were also evident for Mary, who had ties to all grade levels and to the district office upon taking on the coaching role. That these trends aligned across the two coaches is important, given that their schools represent distinct populations, where Chamberlain serves a more affluent student body than Bryant (see Table 1).

Formal and Informal Teacher Leadership

In examining the relationship between formal structures and teacher leadership practice, it is important to consider the potential influence of these structures on informal teacher leadership. That is, in developing infrastructure to support teacher leadership, it seems likely that leadership could shift away from teachers who are not part of these new structures. For example, teachers at Bryant might prefer to go to Emily, as the formal teacher leader, for advice about mathematics. This shift could very well diminish the extent to which other teachers who do not hold formal leadership positions are sought out for advice or information about math.

Our analysis revealed that quite the opposite was true. In APPS, informal teacher leadership was not undermined by the new structures designed to create formal leaders, and in fact may have been supported by them. First, the overall average centrality measures for other teachers (i.e., non-participants in the formal structures) increased across the two years of the study. While it makes sense that teachers' out-degree centrality would increase with the implementation of formal teacher leaders, as teachers were more likely to nominate the new teacher leaders in 2010-11, one might expect the average in-degree for other teachers to decrease. However, the average in-degree for other teachers remained constant from 2009-10 to 2010-11 (see Table 3). This finding indicates that other teachers maintained their overall advice giving, even while teacher leaders were integrated into several schools through new structures.

Brokering among other teachers also increased significantly, from an average betweenness of 10.86 in 2009-10 to 24.81 in 2010-11 ($p<.001$), suggesting that other teachers maintained their influence in their schools' math advice and information networks with the presence of coaches and FM participants. While it is important that other teachers retain a sense of ownership related to instructional improvement (Lieberman & Miller, 2011), the nature of our data collection does not allow us to make claims about whether or not the advice giving and brokering among other teachers supported or countered that of formal teacher leaders. Even so, the observed trends indicate that a symbiotic relationship existed between the formal and informal organizations, where the formal mechanisms put in place to support teacher leadership did not mitigate informal teacher leadership inside schools.

Relationships between New Formal Structures and the Existing Infrastructure

The above findings highlight the relevance of new formal structures in shaping mathematics advice and information networks among school staff. Yet, these new structures were layered onto existing structures that supported teacher leadership practice. As such, it is essential to consider if and how APPS's redesign efforts enabled or constrained its existing teacher leadership infrastructure. Our analysis revealed that the new structures, and particularly the coach initiative, worked in tandem with – or co-habitated – the existing infrastructure thereby allowing teacher leaders to facilitate connections between schools and with the central office.

As shown above, the two full-time math coaches forged ties outside of their schools, primarily to other coaches and to the district office. Our analysis also revealed that, through the existing infrastructure, schools without coaches or Fundamental Math participants still managed to draw upon coaches' expertise. For example, Jim, the principal at Kingsley, described how the coaching structure converged with the array routine to bring math expertise to his school:

> In our case, Chamberlain is part of our array. And, Mary [a math coach] is at Chamberlain, so we're able to benefit. Some of the array staff development we've done has been planned by her, but yet we may have particularly strong teachers from each PLC [at Kingsley] help present it. So Mary may be doing some of the nuts and bolts, but then that whole process is strengthening those people [from Kingsley] to help them be better math leaders at our school. (personal communication, February 2, 2012)

Jim thus drew upon one of the new formal structures as well as the existing infrastructure – the math coach and arrays – to strengthen teacher leadership in math at his school. He used PLCs to embed math leaders across grade-level teams, and he drew upon the array structure to connect team leaders to a math coach at another school. The district infrastructure thus provided Kingsley teachers with expertise in mathematics, thereby increasing the information that was available at the school site. Jim was explicit that developing teachers' leadership capacity was necessary, especially because his school was not included in the district's teacher leadership structures:

> My strategy has tended to be trying to make sure I have those kinds of people brought in as these so-called pockets of leadership throughout the building. We have no math coaches; we don't have anybody participating in Fundamental Math or on the toolbox. I'm forced by simply my own limitations to make sure that I have people around the building, ideally at least somebody in every team, if not at least three or four people through the building that have the ability to answer questions.

Thus, the district infrastructure for teacher leadership in mathematics, both old and new, enabled Jim to infuse teacher leadership in math within his school site. In this way, the established organizational routines generated spillover effects in that they maximized teacher leadership practice in schools that were not officially part of the district's new formal structures.

Moreover, the integration of the knowledge development effort and coaching initiative did not diminish the advice giving and seeking of other teacher leaders in mathematics. That is, the average in-degree, out-degree, and betweenness centralities of the six math toolbox members who were neither coaches nor FM participants increased between the two years of the study, although not significantly (see Table 3). This finding suggests that these teacher leaders were still equally central in their school's advice and information networks and continued to serve as "lifelines" between the school and district office. While this consistency indicates that the new structures did not constrain the existing infrastructure, it could be counterproductive if toolbox members shared different information related to mathematics instruction than coaches or FM participants. Yet, our interviews suggest that this was not the case. For example, even FM participants drew on the expertise of these toolbox members, including John: "If a 1st grade teachers comes to me with a question that I don't know since I'm 2nd grade, then I would send an email to the toolbox representatives of 1st grade [who teach at other schools] to get them the information" (personal communication, January 11, 2011). In checking with a toolbox representative, John ensured that he shared the same information at his school. Thus, the existing structures remained important, even as new formal structures were integrated into the system.

Teachers also utilized their interactions with math toolbox members to influence the district, particularly in the area of assessment. Karen, a 1st grade teacher at Chavez, described her efforts to seek out math toolbox members to express her concerns about particular questions on the district math assessment: "There's several people in the district who are on the math [toolbox] committee, and I will go to them if I have a concern. I did that this year about the wording on an assessment, and then they take it back to that group of people who are responsible for creating the assessments and ask the committee, or they can address it to somebody and then get back to us" (personal communication, February 2, 2012). Thus, toolbox members connected the school to the district and the district to the school, serving as pathways of information, much like instructional coaches have in other studies (e.g., Stein & Coburn, 2008). Overall, these findings indicate that, through purposeful design and redesign, APPS systematically built new formal structures in ways that coalesced with the existing teacher leadership infrastructure.

Discussion

As districts work to improve elementary school instruction, many focus in some way on supporting changes in teachers' instructional practices. Efforts to improve teachers' practice frequently come in the form of new routines or structures, which are often off-the-shelf remedies 'proven' to improve instruction and thereby increase student achievement on standardized tests. These 'off-the-shelf' remedies often fail, however, when little attention is paid to how they might fit into or conflict with the existing district- and school-level organizational infrastructures (Datnow, 2000). Indeed, if adaptation to local contexts is not facilitated in large-scale reform movements, implementation and replication efforts can be thwarted (Peurach, 2011; Peurach & Glazer, 2011). As such, it is critical to attend to the ways in which district redesign efforts can be adapted to work with rather than against existing designs or structures. Our case study of Auburn Park Public Schools allowed us to explore these relationships in the context of instructional reform in mathematics focused on developing teacher leadership.

Findings from our study revealed that district-level changes to formal structures shaped every day practice inside schools. That is, changes to the district infrastructure were associated with shifts in school practice, where teachers who were engaged in new formal structures emerged as key providers and brokers of advice and information about mathematics instruction. Prior research indicates that such changes are not always common, as new structures are often just viewed as formalities that have little influence on practice (Meyer & Rowan, 1977). We thus hypothesize that the manner in which APPS approached its infrastructure redesign made it possible for such changes in school practice to occur. For example, the new structures implemented by APPS worked in tandem with the existing infrastructure to facilitate teacher leaders' advice and information ties both within and between schools. While coaches and Fundamental Math participants emerged as key advice givers and information, math toolbox members, who were part of the existing infrastructure, remained central in their schools' math networks. They also continued to serve as "lifelines" between schools and the central office. Thus, rather than working to supplant the existing infrastructure, the new structures supplemented them in supporting teacher leadership practice.

This supplementary relationship resulted, in part, from the district's strategic efforts to build onto the existing infrastructure for teacher leadership. District administrators carefully selected teachers to participate in the new structures who were already active in the district infrastructure for teacher leadership, serving on the math toolbox and leading array meetings for different schools. As such, there was overlap between the new and existing infrastructures. Additionally, there was overlap between the two new structures that supported teacher leadership, as all three coaches also completed the Fundamental Math program. These strategic efforts made by APPS are important, as very often new structures are put into place without considering existing structures, especially when a leadership or other district-level change occurs (Hargreaves & Fink, 2000). Thus, an important lesson from this case is that districts can build systematically onto existing structures in ways that support district and school practice. Of course, this effort was not entirely seamless, as there were distinct difference in the advice seeking practices between full-time coaches and the part-time coach and FM participants who remained in the classroom. Thus, teachers' leadership capacity likely depends on how they are situated in the overall infrastructure, and such issues should be considered in design efforts.

Additionally, the infrastructure APPS developed to support formal teacher leaders did not undermine informal teacher leadership efforts. Although the new formal structures might have shifted leadership away from informal leaders toward those who held formal positions, our analysis suggested that this was not the case, and in fact, the new structures continued to allow for the emergence of informal teacher leaders. These findings highlight the importance of implementing redesign efforts that work alongside both existing formal and informal structures.

Finally, the very nature of Auburn Park's reform efforts may have facilitated relationships between the new and existing structures as well as the formal and informal organizations. That is, the district's focus on teacher leadership as a mechanism for supporting instructional improvement in mathematics facilitated adaptation at the school level. Rather than requiring the implementation of an off-the-shelf reform model or a one-size-fits-all program that might hinder local adaptation (Datnow, 2005; Glazer & Peurach, 2001), APPS invested in the capacity of a select group of teachers who could then go back to schools and provide guidance and advice to other teachers as needed. While there were some similarities across schools in the formal structures that facilitated staff interactions, there was room for teacher leaders to adapt to their colleagues' needs at the local school site. Moreover, instead of mandating a top-down reform that emphasized hierarchical power relations (Datnow, 2000), the district supported reform through heterarchical structures (Higgins & Bonne, 2011) that tapped into teachers as key sources of advice and direction for instructional improvement in mathematics.

Although it would be convincing to be able to show how changes to APPS' infrastructure led to changes in classroom practice and/or student achievement, we focused in this paper on intermediary changes in school practice. These intermediary changes must be understood first in order to identify how APPS' redesign efforts actually worked to transform instructional practice or to increase achievement. Still, more research is necessary to examine how these changes in school-level practice are related to changes in classroom instruction and, further, how they result in changes in student achievement over time. More work must also be done at the school level to examine how infrastructure is taken up in practice across different local school contexts. Such longitudinal analysis is crucial to understanding the relationships between macro-level changes to policy and infrastructure and micro-level changes to practice inside schools and classrooms.

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Table 1. Elementary School Demographics, Auburn Park School District, 2010-2011

School	Students Enrolled	Percent White	Percent African American	Percent Latina/o	Percent English Learner	Percent Free/ Reduced Lunch
Kingsley	530	92	2	2	0	5
Chamberlain	487	89	3	4	0	5
Torres	484	76	7	9	7	35
Ashton	450	74	5	15	9	34
Bryant	446	78	5	12	0	37
King	441	84	9	3	5	21
Ashe	437	87	3	5	0	5
Chavez	341	70	12	13	9	56
Cisneros	338	89	4	2	0	17
Northvale	324	85	3	6	0	15
Stevenson	282	71	10	11	8	38
Easton	254	86	2	4	0	10

Note: Schools in bold were interview sites.
Source: Nebraska Department of Education (2011).

Table 2. Centrality Measures for Teacher Leaders, 2009-2011

	In-Degree		Out-Degree		Betweenness	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Toolbox Only						
Abby (Bryant)	--	2	--	3	--	0
Chloe (Chamberlain)	2	2	1	4	20	107
Pamela (Chamberlain)	2	2	5	4	3	54
Jodie (Chavez)	2	5	0	2	0	92.5
Brent (Torres)	2	5	2	4	2	126
Patricia (Cisneros)	0	0	0	0	0	0
Fundamental Math Only						
John (Chavez)	5	8	2	2	11.5	76
Laura (King)	7	8	6	8	76.5	317.5
Naomi (Cisneros)	5	8	0	1	0	8.5
Natalie (Stevenson)[a]	3	3	6	0	33.4	0
Alexandria (Easton)	5	6	6	2	52	54
Rachel (Torres)	1	3	1	4	3	97
Coaches						
Emily (Bryant)	7	16	1	8	18	185
Mary (Chamberlain)	6	18	3	10	33.5	545.3
Carmen (Ashton)	6	15	4	1	64	16

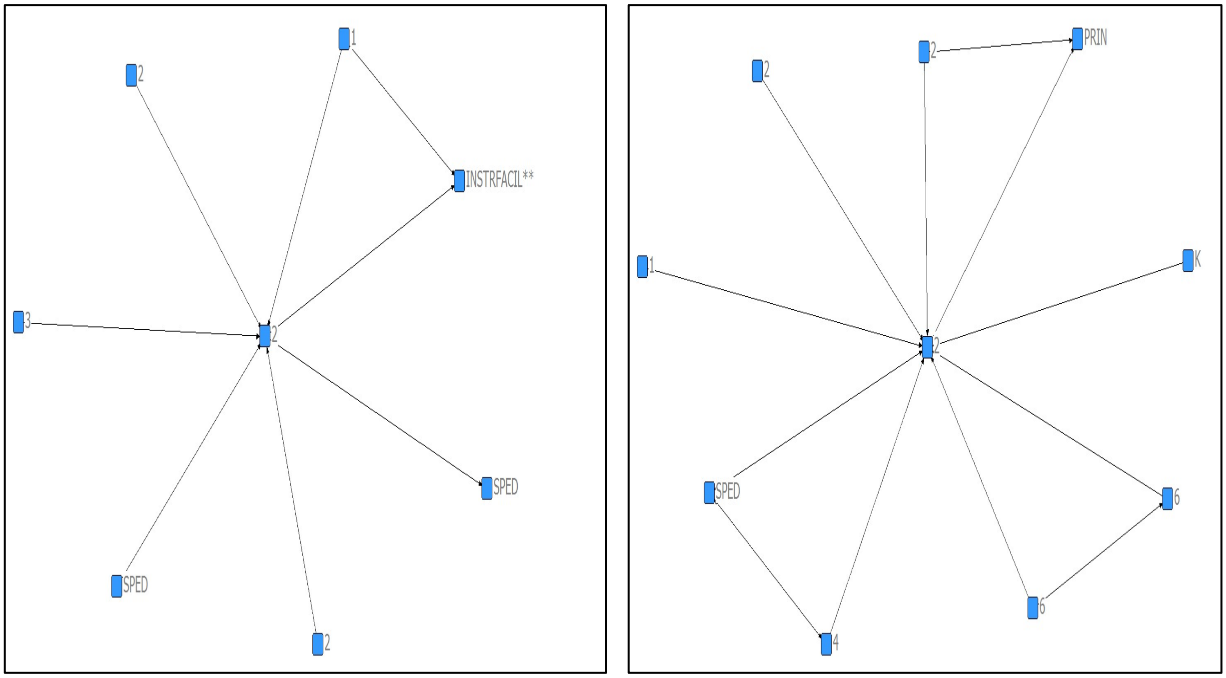
[a]Natalie was the only Fundamental Math participant who was not on the district math toolbox.

Table 3. Mean (SD) Centrality Measures for Teacher Leaders, 2009-2011

	In-degree		Out-degree		Betweenness	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
<u>Toolbox</u>						
All Members (14)	3.69 (2.39)	6.64* (5.76)	2.69 (2.43)	3.64 (3.10)	23.46 (26.48)	123.23* (154.46)
Toolbox Only (6)	1.60 (.89)	2.80 (2.17)	1.60 (2.07)	2.80 (1.79)	5.00 (8.49)	75.80* (49.94)
<u>Fundamental Math</u>						
All Participants (9)	5.00 (1.94)	9.44* (5.57)	3.22 (2.39)	4.00 (3.71)	32.44 (27.0)	144.33+ (181.4)
Fundamental Math Only (6)	4.33 (2.07)	6.00* (2.45)	3.50 (2.81)	3.83 (2.86)	29.33 (30.20)	92.17 (116.89)
Math Coaches (3)	6.33 (.58)	16.33** (1.53)	2.67 (1.53)	6.33 (4.73)	38.67 (23.35)	248.67 (270.19)
Non-Participants (All Other Teachers) (256)	1.54 (1.34)	1.60 (1.26)	1.98 (1.86)	2.21+ (1.84)	10.85 (26.7)	24.81*** (48.07)

Note: Significant differences shown between years. ***p<.001; **p<.01; *p<.05; +p<.10

Figure 1. John’s (Fundamental Math Participant) Individual Math Advice and Information Networks, 2009-10 and 2010-11



Note. We did not collect data from principals related to who they sought out for advice in mathematics; thus, while the qualitative data suggest that Mary Beth went to John for advice about math in 2010-11, the above figure does not show this relationship (i.e., the arrow in Figure 1 does not point from Mary Beth to John).

Figure 2. Emily's (Math Coach and Fundamental Math Participant) Individual Math Advice and Information Networks, 2009-10 and 2010-11