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

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INFRASTRUCTURE REDESIGN AND INSTRUCTIONAL REFORM IN MATHEMATICS

Formal Structure and Teacher Leadership

ABSTRACT

Designing infrastructures to support instruction remains a challenge in educational reform. This article reports on a study of one school system's efforts to redesign its infrastructure for mathematics instruction by promoting teacher leadership. Using social network and interview data from 12 elementary schools, we explore how the district's infrastructure redesign efforts were internally coherent with and built upon existing infrastructure components. We then explore relations between infrastructure and school practice as captured in the instructional advice- and information-seeking interactions among school staff, finding that teacher leaders emerged as central actors and brokers of advice and information about mathematics within and between schools. Further, changes in school advice and information networks were associated with shifts in teachers' beliefs about and practices in mathematics toward inquiry-oriented approaches consistent with district curriculum. We argue that the district's redesign efforts to support teacher leadership coupled district curriculum and school and classroom practice in mathematics.

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SCHOLARS across various traditions acknowledge the critical role of district and school infrastructure in efforts to improve instruction. Although this work identifies aspects of the infrastructure that are associated with instructional improvement, such as shared governance (Bryk & Driscoll, 1985; Newmann & Wehlage, 1995), social trust (Bryk & Schneider, 2002), collaborative work

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structures among teachers (Bullard & Taylor, 1994; Rosenholtz, 1991), and professional development (Desimone, Porter, Garet, Yoon, & Birman, 2002), coupling infrastructure with teaching and learning is an enduring concern (Firestone, 1985; Fuller, 2008; Lampert, Boerst, & Graziani, 2011; Spillane & Burch, 2006; Spillane, Parise, & Sherer, 2011). In this article, we explore relations between infrastructure and school practice through a case of one district's efforts to redesign its infrastructure to support teacher leadership in mathematics.

Some argue that investing in teacher leadership allows teachers to take on responsibility for school-wide instructional improvement (Lieberman & Miller, 1999, 2011; Lieberman, Saxl, & Miles, 1988; Smylie, Conley, & Marks, 2002), which supports change in teachers' practice inside and outside the classroom. Indeed, researchers increasingly recognize the need to attend to sources of leadership beyond the principal (Camburn, Rowan, & Taylor, 2003; Harris, 2005; MacBeath, Oduro, & Waterhouse, 2004; Spillane, 2006b; Spillane, Camburn, & Pareja, 2007; Spillane, Hunt, & Healey, 2009; Timperley, 2005). While much of the teacher leadership literature focuses on the development and experiences of these leaders (York-Barr & Duke, 2004), we argue that teacher leadership must be understood more broadly in relation to the infrastructure that enables and constrains it. Premised on the assumption that the subject matters when it comes to leadership writ large and teacher leadership in particular (Spillane, 2006a), we investigate infrastructure and teacher leadership in mathematics.

We begin by anchoring our work in literature on relations between infrastructure and practice and teacher leadership. Next, we describe our longitudinal research design. Turning to findings, we begin by analyzing how the district redesigned its infrastructure to support mathematics instruction and teacher leadership in mathematics. To examine how this redesign effort influenced school practice, we explore changes in the math instructional advice- and information-seeking interactions among school staff over 3 years, revealing that teacher leaders emerged as central actors and influential brokers of advice and information within and between schools. Further, we examine shifts in teachers' beliefs about and reported practices in mathematics. Based on our analysis, we argue that the district's efforts to redesign its infrastructure to support teacher leadership were coupling mechanisms that tied district-level curriculum to teachers and their instruction. In this way, teacher leaders supported implementation of a district-mandated, inquiry-based mathematics curriculum.

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

National and state educational policies press for improvements in student performance through uniform standards and high-stakes accountability. 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 (Cohen & Spillane, 1992; Cuban, 1990). School districts employ various mechanisms in these efforts, including professional development (Corcoran, Shields, & Zucker, 1998; Garet, Porter, Desimone, Birman, & Yoon, 2001), curriculum adoption (Ball & Cohen, 1996), teacher evaluation systems (Figlio & Kenny, 2005), and instructional coaching (Mangin, 2009). While these approaches each have their merits, school systems must still figure out what combination of reforms will address their needs and how to tailor their organizational infrastructure to support them (Spillane & Coldren, 2011; Spillane et al., 2011).

Infrastructure, or the formal structures that shape practice, is essential to understanding practice in organizations; indeed, "building formalities that work" continues to be a central challenge in organizations (Stinchcombe, 2001, p. 2). This challenge likely persists because infrastructure is often taken for granted and overlooked (Star, 1999). Research suggests that district and school infrastructures are important for school practice (Datnow, Park, & Kennedy-Lewis, 2013; Spillane et al., 2011) and student performance (Lezotte & Passalacqua, 1978; Purkey & Smith, 1983); yet, efforts to redesign public schools indicate that formal structures often tend to be rituals that have little influence on practice (Meyer & Rowan, 1977), or that formal structures get corrupted, intentionally or unintentionally, making changes in instruction difficult (Firestone, 1985; Fuller, 2008).

The concepts of loose coupling and decoupling are often used to account for this disconnect between infrastructure and practice. In general, coupling captures the linkages between organizational elements and the ways in which these elements are responsive to and distinctive from one another (Orton & Weick, 1990). Elements include organizational units (Murphy & Hallinger, 1984) and environments (Weick, 1976), as well as an organization's infrastructure and its core technical work—instruction (Meyer & Rowan, 1977). While tight coupling connotes close linkages among elements that are responsive to each other, loose coupling or decoupling refers to situations in which elements are disconnected and unresponsive. In line with recent scholarship (e.g., Hallett & Ventresca, 2006; Spillane et al., 2011), we draw on coupling as a process, or "something that organizations do, rather than merely as something they have" (Orton & Weick, 1990, p. 218). Our article explores how a district's infrastructure redesign enabled coupling of curricular reform and school and classroom practice.

Teacher Leadership: Infrastructure and Practice

Research identifies various infrastructures that support teacher leadership. Most prominently, instructional coach positions can support changes in classroom practice (Camburn, 2010; Coburn, Choi, & Mata, 2010; Coburn & Russell, 2008; Firestone & Martinez, 2007; Mangin, 2009). The implementation of these formal positions is often in response to federal or state 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 the adoption of curricula (Coburn et al., 2010; Coburn & Russell, 2008).

Studies that attend to infrastructure and teacher leadership show that coach positions can shape school practice, as measured by the nature and quality of staff interactions (Atteberry & Bryk, 2010; Coburn et al., 2010; Coburn & Russell, 2008; Stein & Coburn, 2008). Coaches emerge as central actors in school networks (Atteberry & Bryk, 2010), increasing teachers' access to information and expertise (Coburn & Russell, 2008). Yet, these studies reveal little about how coaches fit into existing school or district infrastructures. These relationships are important, as one study revealed that coaching alone did not influence interactions; careful attention to selection and training and school routines was also critical (Coburn & Russell, 2008).

Our study contributes to this literature by focusing on the structural aspects of teacher leadership.

School and District Practice: Advice and Information Networks

Our work is premised on the notion that research on school administrative practice must extend beyond an exclusive focus on the principal to include other formal leaders (Spillane et al., 2009; Timperley, 2005). We move from school administrative practice as *individual action* to practice as embedded in *interactions* (Spillane, 2006b). Social network analysis allows us to examine school staff interactions while simultaneously attending to the formal organization (Daly, 2010; Moolenaar & Daly, 2012; Ogawa & Bossert, 1995; Pounder, Ogawa, & Adams, 1995). Research consistently points to the importance of the resources for action (e.g., trust, advice, and information) that can be attained through social relations and enable instructional reform and school improvement (Bryk & Schneider, 2002; Frank, Zhao, & Borman, 2004; Lin, 1982, 2001; Louis & Kruse, 1995; McLaughlin & Talbert, 2001; Rosenholtz, 1991; Smylie & Hart, 1999). Our study focuses on advice and information interactions, as advice and information are essential for knowledge development, an important condition for improving instruction (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Elmore, 1996; Hill, 2004).

While research on teacher knowledge development often focuses on formal learning opportunities (e.g., Desimone et al., 2002; Garet et al., 2010; Hill, 2004), teachers also develop knowledge through more informal interactions with colleagues on the job (Parise & Spillane, 2010). On-the-job learning can occur when teachers exchange information and observe one another (Eraut & Hirsh, 2007; Frank et al., 2004; Little, 1993; Smylie, 1995). Thus, teachers' advice and information networks are important to instructional knowledge development (Frank et al., 2004; Reagans & McEvily, 2003), and we used these networks to examine school practice.

Research Approach

We used data collected in one midsized suburban school district in the Midwestern United States, which we refer to as Auburn Park. Drawing on social network and survey data gathered from all of Auburn Park's elementary schools over 3 years, we examined changes in advice- and information-seeking interactions and changes in teachers' beliefs about and reported practices in mathematics, before and after the district's infrastructure redesign. We also used interview data from a purposeful sample of schools and staff as well as central office staff.

In 2010–2011, Auburn Park served 5,630 students in 14 elementary schools. Six schools qualified for Title I funding, while the remaining eight served relatively affluent communities (see Table 1). Although all schools served predominantly White student populations, four schools enrolled more than 10% African American and/or Latina/o students.

School Staff Surveys

In spring 2010, 2011, and 2012, Auburn Park's teaching and administrative staff completed a School Staff Questionnaire focused on aspects of the school organization, including school culture, leadership, and advice- and information-seeking in-

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-Price Lunch
Coach :						
Full-time coach:						
Chamberlain [a]	487	89	3	4	0	5
Bryant [a]	446	78	5	12	0	37
Half-time coach:						
Ashton [a]	450	74	5	15	9	34
Fundamental Math:						
Chavez [a]	341	70	12	13	9	56
Torres	484	76	7	9	7	35
King	441	84	9	3	5	21
Cisneros	338	89	4	2	0	17
Stevenson	282	71	10	11	8	38
Easton	254	86	2	4	0	10
Neither:						
Kingsley [a]	530	92	2	2	0	5
Ashe	437	87	3	5	0	5
Northvale	324	85	3	6	0	15

Note.—Data are not yet available for 2011–2012.
[a] Interview site.

teractions in mathematics and English language arts. High response rates are necessary for social network data to ensure reliable data, ideally at least 80% (Kossinets, 2006; Wasserman & Faust, 1994). Because two schools had below 40% response in 2009–2010, and they did not vary significantly from other schools with respect to demographics or achievement, they were excluded from the analysis. Of the remaining 12 schools, 311 staff members completed the survey in 2010, 337 in 2011, and 375 in 2012, for response rates of 89%, 96%, and 94%, respectively.

School practice measures. To examine school practice in mathematics, we focused on staff interactions as measured using social network items that were previously developed, piloted, and validated (Pitts & Spillane, 2009; Pustejovsky & Spillane, 2009). 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 nominated up to 12 individuals by entering first and last names. Next, respondents indicated the content area related to the advice and/or information they sought from each person: mathematics, reading/English language arts, and other. For this article, we focused on mathematics interactions. Using these data, we generated visual displays of interactions in Netdraw (Borgatti, 2002) and calculated three network centrality measures.

Degree centrality is based on the assumption that actors who are better connected than others are more central in the network (Freeman, 1979). Degree centrality is a count of an actor’s total number of relations, and can be broken into in-degree centrality and out-degree centrality. An actor’s in-degree 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.

Betweenness centrality measures the extent to which an actor links two other actors in the network; betweenness is a measure of brokering, and actors high in betweenness are more prominent in networks (Freeman, 1979). 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 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 counted 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 prominence of teacher leaders in school math networks, we compared average centrality measures for teacher leaders and non-teacher leaders and tested differences for significance using independent *t*-tests. We also compared changes in these measures over 3 years using paired sample *t*-tests. Due to the dependence of variables 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).

Classroom practice measures. To explore relations between infrastructure, school practice, and classroom practice, we examined teachers' beliefs about and reported practices in mathematics over the 3 years. Teachers' beliefs about mathematics were assessed using the Mathematics Attitude Inventory, an 18-item scale adapted from the Fennema-Sherman Short Form (Mulhern & Rae, 1998) for use with teachers (Cronbach's alpha = 0.83). Teachers indicated agreement to each item on a five-point Likert scale. For our purposes, a higher score indicated that teachers believed in the use of inquiry-based approaches to facilitate mathematical learning, while a lower score indicated agreement that the use of directed approaches was more effective. With respect to practices, we used a six-item scale to explore teachers' emphasis on mathematical reasoning and problem-solving practices (Cronbach's alpha = 0.73), developed for the Third International Mathematics and Science Study. Teachers responded to each item with respect to frequency of use on a four-point Likert scale from "never or almost never" to "in every lesson." Changes in teachers' beliefs and reported practices were compared using paired sample *t*-tests in SPSS.

School and Central Office Staff Interviews

As a follow-up to surveys, a subsample of schools, teachers, and administrators were selected for semistructured interviews in spring 2011 and 2012. We selected five schools (as noted in Table 1) to represent a range of organizational structures, such as schools with and without math coaches. We interviewed the principal and four to seven teachers per school, for a total of 33 interviews. We included teachers from different grades as well as teachers who were integrated and some who were isolated in school math networks. We also interviewed Georgia, the district's director of elementary curriculum, and William, the district instructional facilitator.

Questions for school staff elicited information about how and why they interacted with particular individuals about math. In contrast, questions for central office staff focused on district infrastructure and redesign efforts related to teacher leadership in math. Interviews lasted 40–50 minutes and were audio recorded, transcribed, and imported to NVivo 9 for coding and analysis. Analysis included two rounds of coding to identify patterns in the data and to ensure interrater reliability (Miles & Huberman, 1994). In the first round, interviews were open coded (Strauss & Corbin, 1998), and several salient themes emerged. For example, organizational routines emerged as an important reason teachers interacted about math. Other themes related to the infrastructure included professional development and expertise, which were subcoded in several ways: formal position (e.g., coach), specialized training, and general knowledge or interest.

Using these codes, two researchers conducted a second round of coding, during which the coding scheme was refined, and new codes and subcodes were added related to curriculum and planning. The researchers then coded one-third of the interviews and established interrater reliability (Carey, Morgan, & Oxtoby, 1996). This process included coding one interview and meeting to discuss commonalties and discrepancies. The researchers then recoded the interview and again discussed differences. Once kappa coefficients (Fleiss, 1971, 1981) of .85 or greater were achieved, researchers coded four additional interviews. Kappa coefficients for these interviews ranged from .72 to .99; thus, one researcher coded the remaining interviews.

Limitations

In this exploratory study, we make no attempt to generalize beyond the district under study. As such, our findings are limited to the context examined here, although we believe the findings to be useful to similar districts undertaking infrastructure redesign efforts. Our study also examines changes in school practice over just 3 years, limiting the extent to which causal claims can be made about the relationship between infrastructure and practice. Additionally, while we examine the development of advice and information ties among school staff, we cannot offer conclusions related to the content or quality of this advice and information. Moreover, given that our focus is on intermediary changes in school practice as operationalized through teachers' social networks, we did not explicitly examine how infrastructure redesign was related to student outcomes. While we explored changes in teachers' beliefs and reported practices, and we argue that intermediary changes in staff interactions must be understood first to understand how the infrastructure influenced student outcomes, more research is needed to understand the causal relationships between infrastructure, school and classroom practice, and achievement.

Findings

First, we describe Auburn Park's efforts to design and redesign its infrastructure for math instruction. Next, we explore how the infrastructure for teacher leadership in math was related to changes in school practice; then, we examine changes in teachers' beliefs and reported practices.

(Re)Designing Infrastructure to Support Improvement in Mathematics Instruction

Local efforts to design and redesign infrastructure do not take place in a vacuum. New organizational infrastructures are grafted onto existing infrastructures that might work with or against district reform efforts (Datnow, 2005; Peurach & Glazer, 2012); thus, it is important to understand how new structures coalesce or clash with the existing infrastructure.

Auburn Park's infrastructure for mathematics instruction. Auburn Park is situated in a state where English language arts and mathematics content standards were approved for the first time in 2009, and statewide achievement testing began in 2010. As a result of this policy change, Auburn Park officials were concerned about the alignment between state standards and assessments and those developed by the district: "We have always taken pride in that we have our own district standards and assessments. But, do we align with the state? We had to delve into what we were teaching and started that realignment of standards, resources, and assessments" (Georgia, Director of Curriculum, February 2012 interview). Georgia undertook realignment in 2009 with the district's curriculum committees, or toolboxes. Toolboxes for each school subject were designed to bring teachers from different schools together to develop the curriculum for their subject area, align the curriculum to standards, select resources for teaching the curriculum, and write summative assessments.

To support state-district alignment, the math toolbox opted to change the district curriculum to align more closely with the National Council of Teachers of Mathematics (NCTM) Standards (1989, 2000), which support inquiry-based approaches. After adopting this curriculum, toolbox members selected resources, as Georgia described: "We knew what the research said, and we knew the kids had to be actively engaged in their learning; they had to be in an inquiry model. The sit-and-get-lectured model is not effective. So we set those parameters. Then the [toolbox] wrote our curriculum and decided what resources we're going to use to teach that curriculum, instead of the materials telling us what our approach is." The toolbox selected Investigations in Number, Data, and Space, a reform-oriented program supported by the National Science Foundation (Slavin & Lake, 2008). Investigations provides open-ended activities to explore "big mathematical ideas" by engaging in problem solving (Stein & Coburn, 2008, n.p.). Although there has been much debate about teaching mathematics in recent years, centered on the effectiveness of traditional versus more reform-oriented curricula (Schoenfeld, 2004), we found no evidence that the adoption of Investigations was contentious in Auburn Park. While a small number of teachers expressed concerns about teaching math facts, the adoption of the curriculum itself was widely supported across the district, resulting in all Auburn Park elementary schools adopting Investigations partially in fall 2009 and fully in fall 2010.

To support implementation of Investigations, the math toolbox developed units for each grade level that aligned state standards with the curriculum following a process similar to Understanding by Design (UBD) (Wiggins & McTighe, 2005), but modified for the district: "They [toolbox members] took those resources and developed our UBDs for each of the units at each grade level. The UBDs include learning targets, which now are our state standards, and then the concepts and indicators associated with that unit are developed, like your guiding questions, your big understandings, all of your resources, and a suggested pacing" (William, Instructional Facilitator, February 2012 interview). The toolbox then wrote assessments for each unit. The district systematically aligned standards, curriculum, resources, units, and assessments in a way that supported coupling among different components of their infrastructure for mathematics instruction.

Auburn Park's infrastructure for teacher leadership. Auburn Park also cultivated and supported teacher leadership for elementary school mathematics. The existing infrastructure included organizational routines that engaged teachers in leadership for core school subjects, including toolboxes and arrays at the district level and professional learning communities (PLCs) at the school level. In 2010–2011, the district redesigned its infrastructure for mathematics instruction by introducing a professional development effort and a coach initiative to support teacher leadership (see Fig. 1).

Existing Infrastructure Components: Organizational Routines

Organizational routines refer to "a repetitive, recognizable pattern of interdependent actions, involving multiple actors" (Feldman & Pentland, 2003, p. 95). Auburn Park fostered teacher leadership through toolboxes and an array structure that grouped similar schools for professional development. Toolboxes allowed teachers to share expertise and resources within each school subject. According to Georgia, "The power in our toolboxes is that we build capacity in our teachers, and they make good, solid decisions when it comes to selecting a curriculum that's not necessarily the easiest, but it's the right curriculum" (February 2012 interview). Georgia spoke of the adoption of Investigations in 2009, which shifted the district from directed to inquiry-based math instruction. In addition to selecting the curriculum, toolbox members relayed information to other teachers at their schools and helped them to implement it.

Among teachers, toolbox participation indicated content expertise: "If I had a question [about math] I'd go to the two toolbox members because they've been on that math toolbox, so they have good math background knowledge" (Becky, grade 4, Chamberlain, March 2011 interview). Toolbox members were also resources for curriculum issues, as noted by Katie, a grade 6 teacher at Chavez: "I talk to my teammate a lot, the other sixth-grade teacher, because she's on the toolbox. Since those are discussions she has more often as far as curriculum, what it is and why they chose it and where it's going, that's who I go to. She's the lifeline to the central office" (February 2011 interview). The toolbox thus signified content and curricular knowledge, as well as teachers' capacity to serve as "lifelines," or information conduits, between

	2008-2009	2009-2010	2010-2011	2011-2012
Mathematics				
Standards	Language arts and mathematics standards approved			
Assessments		Statewide achievement testing began		
Curriculum and resources	Investigations adopted; aligned units and assessments developed	Two-unit Investigations implementation	Full implementation of Investigations	
Teacher Leadership				
Organizational routines	Toolbox, arrays, and professional learning communities			
Fundamental Math			Participants began Fundamental Math in summer 2010	
Math coaches			Three math coaches assumed roles	Two math coaches remained

Figure 1. Overview of infrastructure changes in Auburn Park, 2009–2012.

the central office and schools, potentially facilitating vertical alignment between levels of the system.

While toolboxes connected schools with the central office, arrays facilitated relationships between schools by bringing teachers together for professional development three times annually. The central office arranged schools into four arrays based on socioeconomic status; Title I schools, for example, were assigned to the same array. Arrays leveraged the teacher leadership developed in toolboxes, as toolbox members were often asked to organize and lead meetings related to the information acquired through their work. Georgia also viewed arrays as an opportunity to develop teacher leaders specifically in math, especially for schools that did not have toolbox members: "In math, we have to do our professional development through arrays. Some buildings don't have toolbox people in math, so they work on professional development in the arrays. We have to bring everybody up, and arrays are a tool we use to build capacity" (February 2012 interview). In addition to fostering ties between teachers in different schools, arrays provided access to teacher leaders who had math content and curricular knowledge.

At the school level, grade-level teams participated in professional learning communities, which involved teachers meeting weekly to discuss instructional issues. Each meeting centered on a different topic, from examining data to lesson planning, as a Kingsley Elementary teacher described: "Our PLC meetings were structured where every week was set up by a topic, and each month we had four topics. There's one PLC dedicated to students. We always had one that looked 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" (January 2012 interview). In addition to grade-level teachers, special education teachers, literacy coaches, and, on occasion, the principal participated. Even so, formal leaders did not lead PLCs, as they were designed to foster teacher leadership: "Teachers very much lead their own 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 to more loosely [managed] as teachers started taking control" (Georgia, March 2012 interview). As PLCs were embedded in school practice, teachers took over organizing and leading meetings.

New Infrastructure Components: Math Professional Development and Coaching

Auburn Park redesigned its infrastructure for teacher leadership in math by introducing two new components. First, the district partnered with a local university to implement Fundamental Math, a professional development program. Fundamental Math included a K–3 Math Specialist certification program and support for participants when they returned to their schools as teachers or coaches. The 18-month program, beginning in summer 2010, featured the NCTM Standards (1989, 2000) and focused on deepening teachers' knowledge of core math topics. Participants were thus exposed to topics covered in Investigations and developed their knowledge of the concepts necessary to support an inquiry-based approach.

District administrators worked with principals to select teachers for Fundamental Math, with each principal nominating a teacher who was a math content expert and had leadership potential. Working to select teachers who were also on the math toolbox, district administrators selected nine teachers from different elementary schools, eight of whom were toolbox members. By selecting teachers from the toolbox, district leaders integrated the professional development effort into the existing infrastructure, rather than layering it as a disconnected add-on.

District redesign efforts also involved the creation of formal teacher leadership positions. In fall 2010, with university funding, Auburn Park instituted math coaches at three elementary schools. Coaches were not new to the district, as every elementary building had a full-time literacy coach. Kelly, the principal at Chamberlain, indicated that the district's success in literacy motivated them 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 this grant from the university that could help do that. Then that commitment would be do we feel like it's effective enough to continue it and to pay for it on our own?" (February 2012 interview). Our analysis supported this claim, with literacy coaches occupying prominent positions in every school's English language arts network; yet, math networks often lacked such central actors prior to the math coach initiative.

Formally full-time teachers, two coaches took on full-time coach positions, and the other took a half-time coach and half-time math teacher position. The full-time positions were district-funded and secured for 3 years, and the half-time position was school-funded and only for 2010–2011. District administrators selected coaches who were known as strong and passionate math teachers, well-respected by colleagues, already known as teacher leaders due to their participation on the toolbox, and enrolled in Fundamental Math. Although there was substantial overlap between the toolbox and these teacher leadership initiatives, the alignment was not seamless, as there were several toolbox members who were neither coaches nor in Fundamental Math. Moreover, five schools had neither Fundamental Math participants nor math coaches. We examine how these differences played out in school practice related to mathematics next.

Teacher Leadership Infrastructure and School Interactions about Mathematics

In the current policy climate, it is tempting to focus on the efficacy of Auburn Park's investments to support teacher leadership. That is, were the new mechanisms to support teacher leadership in math efficacious in improving student learning? Such questions are critical, but generating significant changes in achievement takes time and is dependent on changes in teachers' instruction and opportunities to learn. Thus, other questions must be answered first to understand whether and how Auburn Park's redesign efforts transformed school practice: How does investing in the mathematics knowledge of selected teacher leaders and in coach positions influence those advice and information interactions that are foundational for knowledge development? It is on these intermediate changes in practice that we focus.

To understand how Auburn Park's redesign efforts influenced teachers' advice and information seeking and providing interactions, we first examine Fundamental Math participants' roles in their schools' math networks; then, we turn to coaches. We draw on two cases to illustrate trends in the data, John at Chavez and Emily at Bryant. We selected John and Emily because they were each involved in different components of the district redesign, and their experiences reflected those of their colleagues. John participated in Fundamental Math and remained a classroom teacher; Emily participated in Fundamental Math, and she became a math coach.

John and Emily thus illuminate how different aspects of the infrastructure played out at the individual and school levels.

Fundamental Math Participants in School Mathematics Networks

Our analysis revealed that Fundamental Math was influential in informing teachers' advice seeking, as the average in-degree of participants increased significantly ($p < .05$) after enrolling. Before the program began in 2009–2010, participants' average in-degree was 5.0; in 2010–2011, this average increased to 9.4. This shift indicates that an average of four additional staff members nominated these teachers as individuals they went to for advice or information about math (see Table 2). Participants' average in-degree continued to increase in 2011–2012, to 10.0. Conversely, nonparticipants' average in-degree remained constant. The significant increase in Fundamental Math participants' in-degree remained upon removing coaches from the sample (4.3 in 2009–2010 to 6.0 in 2010–2011; $p < .05$), suggesting that the professional development in itself mattered for whether these teachers were sought out for advice or information.

In John's case, five teachers nominated him as someone they went to for advice or information about math in 2009–2010 (see Table 3 and Fig. 2); the next year, eight teachers nominated him, and in the third year, 11 teachers. John thus became an increasingly central actor in his school's math network. Teachers' accounts supported these findings. Karen, a grade 1 teacher at Chavez, discussed the importance of John's participation in Fundamental Math: "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] (March 2011 interview). For Karen, John's participation made him "a math person" with particular knowledge in that subject. In addition, John developed a relationship with his principal, Mary Beth. Although Mary Beth was not part of John's network in 2009–2010, she was in 2010–2011 and 2011–2012 (see Fig. 2). Mary Beth described how Fundamental Math changed their relationship: "It's been in the last year [since Fundamental Math] that I've seen his strong interest in leadership in math. I speak regularly with him about math instruction and staff development and what we need to be doing. He's inspired by the program, and we talk about what he observes. He's never critical of teachers, and I think they are aware of that and go to him easily, and he can be a sounding board to me" (February 2011 interview). John served as an advisor and "sounding board" to Mary Beth, and he maintained nonevaluative relationships with teachers.

Similarly, 14 of the 20 interviewed staff members in Fundamental Math schools mentioned the program as a reason they sought out a colleague for advice about math. Kelly, the principal at Bryant, described reaching out to the Fundamental Math participant at her school: "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" (March 2012 interview), and Andrea, a grade 3 teacher at Ashton, spoke about her school's Fundamental Math participant: "I respect [Carmen's] opinion; she knows a lot about math, and she's learning more all the time. She's taking classes, and she's able to show me new things" (April 2011 interview).

Fundamental Math participants also took on brokering roles, as measured by changes in their average betweenness centrality, a gauge of their brokering of rela-

Table 2. Mean (*SD*) Centrality Measures for Teacher Leaders and Other Teachers, 2009–2011

	In-Degree			Out-Degree			Betweenness		
	2009–2010	2010–2011	2011–2012	2009–2010	2010–2011	2011–2012	2009–2010	2010–2011	2011–2012
Toolbox:									
All members (14)	3.7	6.6*	6.8	2.7	3.64	3.6	23.5	123.2*	95.1
	(2.4)	(5.7)	(6.9)	(2.4)	(3.1)	(3.7)	(26.5)	(154.5)	(138.7)
Toolbox only (6)	1.6	2.8	2.7	1.6	2.80	2.7	5.0	75.8*	48.9
	(.9)	(2.2)	(1.5)	(2.1)	(1.8)	(2.5)	(8.5)	(49.9)	(51.3)
Fundamental Math:									
All participants (9)	5.0	9.4*	10.0	3.2	4.0	3.9	32.4	144.3+	115.4
	(1.9)	(5.6)	(7.4)	(2.4)	(3.7)	(4.3)	(27.0)	(181.4)	(169.3)
Fundamental Math only (6)	4.3	6.0*	6.0	3.5	2.8	2.8	29.3	92.2	61.6
	(2.1)	(2.5)	(5.3)	(2.8)	(2.9)	(3.7)	(30.2)	(116.9)	(144.0)
Math coaches (3)	6.3	16.3**	18.0	2.7	6.3	6.0	38.7	248.7	223.0
	(.6)	(1.5)	(2.0)	(1.5)	(4.7)	(5.6)	(23.4)	(270.2)	(192.0)
Nonparticipants (256) (all other teachers)	1.5	1.6	1.4	2.0	2.2+	1.7***	10.9	24.8***	11.9***
	(1.3)	(1.3)	(1.6)	(1.9)	(1.8)	(1.6)	(26.7)	(48.1)	(33.1)

Note.—Significant differences shown between years (i.e., if the value is significantly different than the prior year).
+ $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 3. Centrality Measures for Teacher Leaders, 2009–2012

	In-Degree			Out-Degree			Betweenness		
	2009–2010	2010–2011	2011–2012	2009–2010	2010–2011	2011–2012	2009–2010	2010–2011	2011–2012
Toolbox only:									
Abby (Bryant)	–	2	3	–	3	5	–	0	29.0
Chloe (Chamberlain)	2	2	3	1	4	3	3.0	54.0	40.6
Pamela (Chamberlain)	2	2	4	5	4	6	20.0	107.0	115.1
Jodie (Chavez)	2	5	4	0	2	2	0	92.5	108.5
Brent (Torres)	2	5	–	2	4	–	2	126	–
Patricia (Cisneros)	0	1	2	0	0	–	0	0	–
Fundamental Math only:									
John (Chavez)	5	8	11	2	2	–	11.5	76	–
Laura (King)	7	8	12	6	8	7	76.5	317.5	355.3
Naomi (Cisneros)	5	8	8	0	1	–	0	8.5	–
Natalie (Stevenson) [a]	3	3	5	6	0	2	33.4	0	14.5
Alexandria (Easton)	5	6	0	6	2	8	52	54	0
Rachel (Torres)	1	3	–	1	4	–	3	97	–
Coaches:									
Emily (Bryant)	7	16	20	1	8	7	18	185	109.0
Mary (Chamberlain)	6	18	18	3	10	12	33.5	545.0	444.5
Carmen (Ashton)	6	15	16	4	1	1	64	16	115.3

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

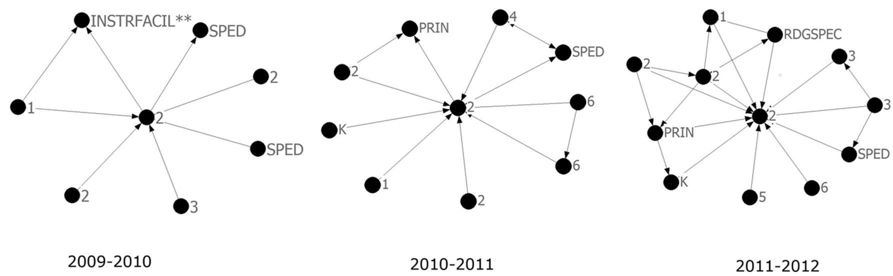

Figure 2. John's (Fundamental Math participant) individual math advice and information networks, 2009–2012. (Note: We did not collect data from principals related to who they sought out for advice in mathematics; thus, while the qualitative data suggest that Mary Beth went to John for advice about math in 2010–2011, the above figure does not show this relationship; i.e., the arrow in the second panel does not point from Mary Beth to John). **indicates a central office staff member.

tions among staff. Participants' average betweenness increased from 32.4 in 2009–2010 to 144.3 in 2010–2011 (see Table 2). Though only marginally significant ($p < .10$), this change is substantial when compared to other teachers, whose average betweenness changed from 10.9 to 24.8. Moreover, there was a significant difference in the average betweenness of participants and nonparticipants in years 2 and 3 ($p < .01$), but not in year 1, indicating that participants occupied greater brokering roles after starting Fundamental Math. This finding also held when excluding coaches.

John emerged as a broker of information about math across more grade levels and became more influential in those relationships. In 2009–2010, John only had ties to grades 1–3 and special education; in 2010–2011, he had connections with grades K–2, 4, 6, and special education, and in 2011–2012, he added a grade 5 teacher and a reading specialist to his network (see Fig. 2). Moreover, John became a more influential broker, forming two new closed triadic relationships in 2010–2011, and eight in 2011–2012. Closed triads, where two actors who are tied to a third actor are also tied to each other, are considered longer lasting than other types of ties and to have the greatest capacity for influence (Krackhardt, 1998; Simmel, 1950). Thus, as John formed more closed triads, we argue that he became more influential in his school's network. Indeed, Fundamental Math participants, including John, credited the program for increased brokering: "I think that especially with being in Fundamental Math my confidence in my math ability and teaching has gotten a lot greater, and I've been able to bring a lot of that back and share with staff. I think they've started to see that I'm willing to take that role, and I think they kind of want that" (February 2011 interview). On top of marking John with expertise, Fundamental Math increased his confidence and motivated him to share ideas about math instruction.

Mathematics Coaches in School Mathematics Networks

Among Fundamental Math participants, coaches stood out as leaders, with the formal position signaling that they were go-to experts and increasing the extent to which colleagues sought them out for advice and information about math. In 2009–2010, coaches' average in-degree was 6.3; in 2010–2011, it increased significantly ($p < .01$) to 16.3 (see Table 2), indicating that an average of 10 more teachers nominated them as individuals whom they sought out for advice. Coaches' average in-degree continued to increase in 2011–2012, to 18.0. Overall, coaches were sought out more often than other teachers, including Fundamental Math participants.

The increase in advice giving among coaches was evident in Emily's math network. While Emily, Bryant's coach, had seven incoming ties in 2009–2010, she had 16 such ties in 2010–2011, and 20 in 2011–2012 (see Table 3 and Fig. 3). Angie, a special education teacher, described how Emily became the "go-to" person in mathematics: "[Emily] wasn't our facilitator [last year]. She was just a third-grade teacher. I knew she had a wealth of knowledge, I just wasn't in [her classroom] when she was teaching math. *Now that she's moved into this math facilitator position*, that's different. She's been trained, and she knows a lot about math. I just trust that she has a lot of knowledge on it; she's been studying it. She's the go-to person" [emphasis added] (March 2011 interview). Whereas she viewed Emily as "just a third-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, it was not simply that Emily assumed a new 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, it was a combination of Emily's position and expertise in math that was at play.

While both formal position and professional development informed teachers' advice seeking, the coach position in itself served as an explicit marker of expertise. When asked why she went to Mary, the coach at Chamberlain, for advice, Jessica, a grade 2 teacher, put it simply: "Because she's our math coach. She's supposed to know it" (February 2012 interview). In fact, the influence of the coach position on teachers' advice seeking persisted even after Carmen, the half-time coach at Ashton in 2010–2011, returned to the classroom full time and no longer held the position the following year. The increase in the number of teachers seeking Carmen out for advice remained high in 2011–2012 (see Table 3). It thus appears that once teachers assume a formal position, other teachers begin to view them as an expert, and this perception remains even in the absence of the formal position. One interpretation of this finding is that school staff used knowledge encoded externally (e.g., in formal positions and training), enabling them to utilize the knowledge of colleagues, what scholars refer to as transactive memory (Moreland & Argote, 2003; Wegner, 1987, 1995).

With respect to coaches' own advice and information seeking, it was the full-time coaches who reported reaching out more often. Full-time coaches reached out to seven more individuals for advice about math upon assuming their positions (see Table 3). In contrast, the out-degree for the half-time coach decreased. These differences are likely related to the amount of time coaches had available. Without class-

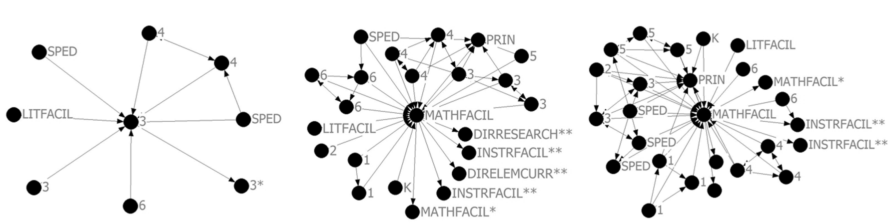

Figure 3. Emily's (math coach and Fundamental Math participant) individual math advice and information networks, 2009–2012. *indicates staff at another school; **indicates a central office staff member.

room responsibilities, Mary focused on supporting teachers: "I think [my interactions] changed [after becoming the coach] in a sense that I wasn't in a classroom, so now I have time to support teachers. I have time to be in their classrooms, to go to their PLCs. 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" (February 2012 interview). As a full-time coach, Mary interacted with colleagues in a variety of activities that supported their math instruction. On the other hand, Carmen had only mornings set aside for coaching. Since teachers taught math in the afternoon, she could not observe in classrooms and spent most mornings waiting for teachers to visit: "In the morning, [my classroom] is my home base, so teachers just come here" (March 2011 interview). The school schedule and time allotted for coaching thus affected Carmen's ability to assume coaching responsibilities.

The limitations Carmen experienced were also evident among Fundamental Math participants who remained classroom teachers. In general, this group did not experience substantial shifts in their out-degree centralities. John, for example, continued to go to just two staff members for advice and information about math (see Table 3). As was the case for Carmen, this trend is likely related to the lack of time that participants had to reach out to others. These findings point to the importance of a holistic approach to infrastructure redesign, where teacher leaders' ability to take advantage of their role depends on how they are situated in the overall school structure.

Coaches, like other Fundamental Math participants, emerged as central brokers of advice and information about math. Whereas Fundamental Math participants tended to broker relationships within schools, full-time coaches served as brokers within schools and between schools and the central office. The betweenness of full-time coaches increased dramatically after assuming their positions and remained high in the third year (see Table 3). In Emily's case, her interactions primarily focused on higher grade levels within her school in 2009–2010, with ties to grades 3, 4, and 6, special education, the literacy coach, and a teacher (Mary) at another school. In 2010–2011, Emily interacted with at least one teacher at every grade level, as well as the special education teacher, literacy coach, and principal; she also added four ties to the central office. In 2011–2012, Emily's interactions continued to expand (see Fig. 3). Thus, like John, Emily brokered information across more grade levels and between teachers and the principal. However, Emily also served as a broker between her school and the central office. Emily described how her responsibilities facilitated brokering: "My involvement at the school and district changed because of my position as math coach. I'm constantly trying to be in classes to observe, I'm coaching, I'm talking to teachers, I have district meetings, I work with the other coach, we get together and provide staff developments" (April 2011 interview). Emily's reach inside and outside her school indicates that there was some level of coherence between the district and school. Moreover, Emily forged 17 new closed triads in 2010–2011, and 15 new closed triads in 2011–2012, suggesting that she became a highly influential broker and that her influence increased over time. These increased tie spans are important for developing new knowledge and facilitating innovation (Granovetter, 1983; Tsai, 2001), indicating that the formal position enhanced Emily's knowledge as well as the knowledge of those with whom she interacted. These relationships were also evident for Mary. That these trends aligned for the full-time coaches is important, as their schools represent distinct populations, where Chamberlain served a more affluent student body than Bryant (see Table 1).

An alternative hypothesis that could explain the increased centrality of Fundamental Math participants and coaches in school math networks is that there was an overall shift in advice-seeking interactions stemming from the district's mathematics curriculum adoption. We examined this hypothesis, but found that, while the average in-degree and betweenness centralities for Fundamental Math participants and coaches increased significantly, the average in-degree and betweenness for all other teachers remained relatively constant across the 3 years. That the overall advice seeking of other teachers did not change, and that of Fundamental Math participants and coaches did, suggests that it was the new infrastructure for teacher leadership in math that supported increased interactions, rather than the curriculum change. Further, changes that occurred in Fundamental Math and coach schools were not evident in schools that did not have teacher leaders. Given that the curriculum was adopted across all elementary schools, yet changes in interactions were only evident in Fundamental Math and coach schools, we conclude that changes in school practice were primarily related to the redesigned infrastructure that supported teacher leadership in math.

Internal Coherence among Components of the Teacher Leadership Infrastructure

Our account has focused on relations between district redesign efforts and school math networks. Yet the professional development and coaching efforts were layered onto organizational routines that supported teacher leadership. In this section, we describe how elements of the redesigned infrastructure reinforced these existing infrastructure elements.

Schools without coaches or Fundamental Math participants engaged organizational routines to draw upon coaches' expertise. Jim, the principal at Kingsley, described how the coach initiative converged with the array to bring math expertise to the school: "In our case, Chamberlain is in 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 strong teachers from each PLC [at Kingsley] help present it. So Mary may be doing the nuts and bolts, but we are strengthening people [from Kingsley] to help them be better math leaders at our school" (February 2012 interview). Jim used PLCs to embed teacher leaders across grade-level teams and the array to connect grade-level leaders to a math coach. In this way, the existing infrastructure provided teachers at Kingsley with mathematics expertise, thereby increasing the information available. Developing teachers' leadership capacity was necessary, according to Jim: "My strategy has tended to be trying to make sure I have people brought in as pockets of leadership throughout the building. We have no math coaches; we don't have anybody participating in Fundamental Math. I'm forced by 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" (February 2012 interview). The organizational routines enabled Jim to infuse teacher leadership in math within his school. Existing infrastructure components thus enabled spillover effects in that they maximized teacher leadership in schools that were not part of the redesign efforts.

Moreover, the integration of professional development and coaching did not diminish the advice giving and seeking of other teacher leaders. The average in-degree, out-degree, and betweenness of math toolbox members who were neither coaches nor in Fundamental Math increased between 2009–2010 and 2010–2011, though not significantly (see Table 2). This finding suggests that toolbox members remained as central in school math networks and continued to serve as "lifelines" to the central office. This consistency indicates that new infrastructure components did not constrain existing components. Even so, it could be counterproductive if toolbox members shared different information than coaches or Fundamental Math participants; yet, interviews suggested that this was not the case. Fundamental Math participants drew on toolbox expertise, including John: "If a grade 1 teacher comes to me with a question that I don't know since I'm grade 2, then I send an email to the toolbox representatives of grade 1 to get the information" (February 2011 interview). The math toolbox thus remained important, even with new components integrated into the infrastructure for mathematics instruction. Overall, these findings indicate that, through purposeful design and redesign, Auburn Park systematically built upon its teacher leadership infrastructure in ways that supported practice district-wide.

Teacher Leadership Infrastructure and Classroom Practice

Thus far, we have described the district's infrastructure redesign efforts and how they were associated with changes in school practice. We now briefly explore whether or not the infrastructure redesign was associated with changes in classroom practice. Between 2009 and 2012, when we observed changes in school practice, teachers' beliefs about and reported practices in mathematics also shifted significantly (see Table 4). These shifts indicate that, on average, teachers developed more inquiry-oriented beliefs about teaching mathematics, and they reported an increased use of practices that aligned with these beliefs. These shifts are consistent with the ideas emphasized by Investigations.

These findings helped us generate hypotheses about the relationships between infrastructure, school practice, and classroom practice. First, given that advice and information are critical for knowledge development, we hypothesize that changes in school math networks were important catalysts for the observed shifts in teachers' beliefs about and practices in mathematics. Then, because new infrastructure components stimulated these changes in school math networks, we argue that these components were coupling mechanisms that connected the district-level curriculum with classroom practice in mathematics.

Table 4. Change in Teachers' Beliefs and Reported Practices Related to Mathematics ($n = 270$)

	2009–2010	2010–2011	2011–2012
Beliefs about mathematics instruction	3.35	3.46***	3.51***
	(.5)	(.5)	(.5)
Reasoning and problem-solving practices	2.39	2.52***	2.64***
	(.4)	(.4)	(.5)

Note.—Significant differences are for comparisons to 2009–2010.
*** $p < .001$.

Discussion

We examined relations between organizational infrastructure and school and classroom practice through one district's efforts to redesign its infrastructure for mathematics instruction and teacher leadership. Findings revealed that efforts to integrate new infrastructure components, including professional development for select teacher leaders and a coach position, facilitated staff interactions about elementary math instruction. In turn, teachers' beliefs about and reported practices in math shifted in ways that aligned with the district's mathematics curriculum.

Using Auburn Park as a case of local school system infrastructural redesign in elementary mathematics, our analysis contributes in at least four ways to a growing body of literature on teacher leadership and school reform. First, building on work that highlights coaches' capacity to increase teachers' access to information (Atteberry & Bryk, 2010; Coburn & Russell, 2008), our study reveals the importance of professional development and coach positions for influencing school practice. In providing carefully selected teachers professional development in math, Auburn Park enabled school staff interactions in that subject, and the creation of coach positions for select professional development participants had an even greater influence on interactions. These teacher leadership efforts enabled school practice even in schools that were not directly touched by them.

Second, a defining characteristic of Auburn Park's redesign efforts was the intentional alignment of professional development and coaches with existing infrastructures (e.g., toolboxes, arrays). Districts and schools often adopt multiple reforms that are layered onto infrastructures without much thought for integration (Newman, Smith, Allensworth, & Bryk, 2001). Further, reforms are often weakly tied to curriculum in a particular subject. These trends can produce "Christmas tree schools" that purchase several programs without assessing quality or coordinating them in ways that strengthen the organizational core (Bryk, Easton, Kerbow, Rollow, & Sebring, 1993, p. 14). In contrast, Auburn Park's new infrastructure for teacher leadership was integrated and aligned with the district's infrastructure for math instruction. Integration was accomplished by selecting teachers for professional development and coaching who already engaged in teacher leadership on the math toolbox. Moreover, the professional development aligned with the math curriculum, as both supported inquiry-focused NCTM standards. This integration and alignment supported coherence across infrastructure components and a focused vision for mathematics instruction.

Third, our study captures how a local school system's infrastructure for mathematics can enable interactions about mathematics among school staff. Auburn Park's addition of infrastructure components to support teacher leadership in math was associated with increases in staff advice and information interactions about mathematics. Teacher leaders became more central actors and influential brokers of advice and information about math, and they forged connections with the central office. In this way, Auburn Park's redesigned infrastructure influenced school-level practice. Based on our analysis, we argue that design efforts that integrate and align components of a district infrastructure can influence practice in schools. Further, our account shows how these changes in school practice were associated with teachers' beliefs about and reported practices in math becoming consistent with the district curriculum.

Fourth, our account more broadly illuminates how a local school district can enable coupling of curriculum initiatives with instruction by redesigning its infrastructure to support teacher leadership. Teacher leaders, both coaches and professional development participants, contributed to increases in advice and information interactions about mathematics among school staff that were also associated with shifts in teachers' beliefs about and practices in mathematics that aligned with the district's inquiry-based curriculum. By transforming work practice in schools, teacher leadership coupled mathematics curriculum and mathematics teaching, as facilitated through purposeful design and redesign of a local school system's infrastructure.

Though tempting, especially in the current research climate, to parse out the independent effects of each infrastructural component (e.g., coaches, professional development, organizational routines, curriculum) from one another, our account suggests that understanding how these components work together—as a more or less coherent infrastructure for teacher leadership and more or less coupled with math instruction—is also important. As evident in Auburn Park's redesign efforts, school systems (in this case a local school district) often implement changes to multiple components of their infrastructure at once. As a result, in the real world it is often difficult (and indeed problematic) to attribute change to any one component. While we acknowledge the importance of knowing whether coaching or curriculum or any other infrastructure component is efficacious in producing change in practice, it is also important to understand how changes to the infrastructure occur together and whether and how they together enable change in practice. Our analysis of Auburn Park documents such an effort.

Using Auburn Park as a case of infrastructure redesign, we consider lessons for other school districts and perhaps other levels of education systems. There are limitations of focusing in on any one level of an education system in isolation (but it is also inevitable), as what happens at one level with respect to leading and managing instruction is interdependent with other levels—classroom, school, local, state, and federal—and indeed extra-system agencies (e.g., textbook publishers, testing agencies). One interpretation is that our account captures the extensive work left to local districts and school leaders to design and redesign infrastructures in the United States, where the federal and state education systems have historically been fragmented with respect to providing an infrastructure that supports instruction (Cohen & Moffitt, 2009).

Our case study can be extrapolated from with some careful and thoughtful adaptations to other education systems. Education systems across the globe can be thought of as consisting of an infrastructure that more or less supports their core work—instruction. What level of these systems takes primary responsibility for different components of the infrastructure and the extent to which the infrastructure coheres within and between levels will vary (e.g., the school, local government, state, national ministry). Still, identifying the components and key characteristics of these infrastructures will enable cross-national comparisons that contribute to our understanding of relations between educational infrastructure and everyday practice in educational systems (Spillane & Kenney, 2012).

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