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Policy makers increasingly include provisions aimed at fostering professional community as part of reform initiatives. Yet little is known about the impact of policy on teachers' professional relations in schools. Drawing theoretically from social capital theory and methodologically from qualitative social network analysis, this article explores how district policies influence teachers' social networks in eight elementary schools in two districts involved in the scale-up of mathematics curriculum. It is argued that policy affects whom teachers seek out for discussion of mathematics instruction but that differences in policy provisions lead to variations in the nature and quality of interactions. Furthermore, school leaders mediate district policy, thereby influencing these patterns of interaction. By uncovering the dynamics by which policy influences teachers' social networks, this article contributes to understandings of the factors that foster the development of social capital. It also uncovers opportunities for intervention for those designing policy initiatives to support implementation of instructional innovations.

Keywords: *teachers' social networks, district policy, curriculum implementation*

THERE is accumulating evidence that teachers' professional communities play an important role in policy implementation (Coburn, 2001; Elmore, Peterson, & McCarthey, 1996; Frank, Zhao, & Borman, 2004; Knapp, 1997; Louis, Marks, & Kruse, 1996; McLaughlin & Talbert, 2001; Newmann, King, & Youngs, 2000; Smylie & Hart, 1999). Compared to teachers without these social supports, teachers in schools with strong professional communities are more likely to make changes in their instructional practice (Elmore et al., 1996; Louis et al., 1996; Louis & Marks, 1998; Newmann et al., 1996; Newmann et al., 2000) and produce increases in student learning (Lee & Smith, 1996; Louis & Marks, 1998; Rosenholtz, 1991; Yasumoto, Uekawa, &

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Bidwell, 2001). Prior research suggests that professional communities can provide the necessary trust for risk taking (Bryk & Schneider, 2002; Louis et al., 1996; Newmann et al., 2000), access to expertise to support learning (Frank et al., 2004; McLaughlin & Talbert, 2001), and opportunities for teachers to negotiate the meaning and implications of reform (Coburn, 2001, 2006).

In recent years, policy makers and reformers have begun to include provisions intended to foster teacher professional community as part of policy and reform initiatives. Many reform initiatives include time for teachers to meet, the provision of coaches to increase teachers' access to expertise, and activities that require teachers to engage with their colleagues around issues of teaching and learning (e.g., looking at student data; McLaughlin & Talbert, 2006; Westheimer, 1998). Yet there have been virtually no studies of the impact of policy interventions on teachers' professional relations in schools. Put more sociologically, we know little about how the traditional bureaucratic mechanisms of policy influence what is at root an emergent and perhaps professionally governed phenomenon.

Here, we engage in an exploratory study of the role of policy in the nature and configuration of teachers' social networks. We draw on data from a study of districtwide scale-up of mathematics curricula in two urban school districts. More than ever before, school districts are creating systems of instructional guidance, including professional development and coaching, to support teachers as they learn to implement new curricula (Darling-Hammond et al., 2003; Hightower, Knapp, Marsh, & McLaughlin, 2002; Snipes, Doolittle, & Herlihe, 2002). These support systems frequently include structured opportunities for teachers to learn from one another and more experienced others. The two districts in our study were no exception: In addition to the more typical provision of professional development from the curriculum publisher, both districts developed a coaching structure as the central mechanism to provide teachers with access to expertise in the new curriculum at their school site; both required schools to provide biweekly after-school professional development on the new mathematics curricula for the entire school staff; and both created time in the schedule for teachers to meet weekly in grade-level groups during the school day. In this article, we investigate how these new structures—and other aspects of the rollout of the curriculum—influenced teachers' interactions with one another about mathematics.

We draw theoretically from social capital theory, which has been profitably used to understand how individuals draw on resources available to them by virtue of their position in a network of social relations to attain a number of valued outcomes—including increased human capital, diffusion of implementation, and reform implementation (Coleman, 1988; Frank et al., 2004; Nahapiet & Ghoshal, 1998; Penuel, Riel, Krause, & Frank, in press). However, few studies have investigated how social policy influences the development and change of patterns in social networks (Adler & Kwon, 2002), and none have done so in the context of public schools. In the absence of well-developed theory in this area, this article proposes to generate theory (i.e., rather than test hypotheses derived from existing theory). Specifically, we seek to identify key features of the district policy that appear to influence the nature and quality of teachers' social network, and we seek to elucidate the mechanisms by which this influence occurs.

Given our review of the literature on social capital and social networks, we suggest that four dimensions of teachers' professional relations are potentially important for reform implementation: structure of ties, access to expertise, trust, and the content of interaction. We then employ qualitative social network analysis to analyze how policy initiatives influence these dimensions of teachers' networks in eight elementary schools in the two districts. We provide evidence that district policy does influence the nature and quality of teachers' social networks, fostering increased tie span, access to expertise, and depth of interaction. However, the design of the initiative matters and is mediated at the school level by leadership decisions that influence the way that coaches are used and the degree to which talk is congruent with the initiative. By uncovering the dynamics by which policy efforts influence the nature of teachers' social networks, we contribute to theoretical understandings of the factors that foster the development of social capital. We also uncover strategic opportunities for intervention for those designing policy initiatives to support the implementation of instructional innovations in schools.

Social Capital Approach and Teacher Professional Community

The last decade has witnessed an explosion of interest in teachers' professional communities, or what Louis et al. (1996) describe as "teachers' collective engagement in sustained efforts to improve practices" (p. 758). As a reform strategy, professional community aims to encourage teachers to share ideas, discuss teaching strategies, and work together in planning, teaching, and advising in an effort to reduce isolation, facilitate stronger professional connections, and foster positive changes in instructional practices (Lampert, 1991; Lieberman, 1988, 1995; McLaughlin, 1993; Shulman, 1987).

Although studies vary in how they define *professional community*, they generally conceptualize it as including such dimensions as shared norms and values, a focus on student learning, social trust, deprivatization of practice, collective responsibility, and collaboration (Elmore et al., 1996; Grossman, Wineberg & Woolworth, 2001; Louis et al., 1996; Louis & Marks, 1998; Newmann et al., 1996; Newmann et al., 2000). Early research in this tradition provides evidence that schools with strong professional communities show a range of valued outcomes from teacher learning (Grossman et al., 2001; Little, 2003; McLaughlin & Talbert, 2001; Rosenholtz, 1991) to changes in classroom practice (Elmore et al., 1996) and implementation of reform (Louis et al., 1996; Louis & Marks, 1998; Newmann et al., 1996; Newmann et al., 2000).

However, although this research has been useful in highlighting the important role of teachers' social relations in improvement efforts, it has several conceptual and methodological limitations. First, the existing research provides limited insight into the mechanisms by which teachers' professional relations represent a resource for instructional improvement (Little, 2003; Penuel et al., in press). The research identifies key dimensions that seem to distinguish strong versus weak communities, but it does not directly study the mechanisms by which these dimensions lead to greater teacher learning or instructional change. Second, these studies typically assume in advance the locus of professional community, focusing on the school as the unit of analysis or on formal organizational structures such as grade-level groups and departments. Yet we know that teachers are often embedded in a network of relations that span multiple subgroups and include individuals inside and outside school boundaries (Bidwell & Yasumoto, 1999; Coburn, 2001; Penuel et al., in press; Spillane, 2005; Yasumoto et al., 2001). Furthermore, in some circumstances, informal structures are more consequential than formal organizational structures as places where teachers interact with one another (Brown & Duguid, 1991; Coburn, 2001; Frank & Zhao, 2004; Reagans & McEvily, 2003; Stoelinga, 2008; Wenger, 1998; Zahorik, 1987). Finally, much existing research on teacher professional community assumes that interaction in communities is always positive and thus supports reform implementation. However, a few studies provide evidence that collegial interactions can reinforce norms of privacy and existing instructional practices (Achinstein, 2002; Little, 1982, 1990) or become contrived collegiality as teachers are invited or required to collaborate—but on agendas set by others (Hargreaves, 1991).

A Social Capital Approach to Professional Community

Social capital theory presents an opportunity to address these conceptual and methodological limitations. *Social capital* is defined as "the resource available to actors as a function of their location in the structure of social relations" (Adler & Kwon, 2002, p. 18). This approach pays careful attention to the way that individuals are situated in social networks and how social ties enable such individuals to access and make use of valued resources (Coleman, 1990; Portes, 1998). When applied to education, social capital theory foregrounds the resources that are available to a teacher through social interaction with colleagues, and it posits that particular features of social relations are more or less conducive to accessing appropriate resources and creating a normative environment that enables change in classroom practice.

Many social capital theorists also draw on a methodological approach called *social network analysis* as a means to investigate the relevant features of teachers' social relations. This approach involves systematically mapping

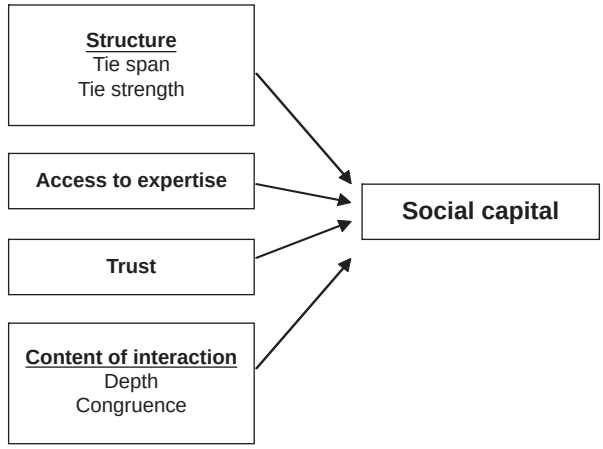

FIGURE 1. *Sources of social capital.*

patterns of interpersonal communication and determining who interacts with whom. As such, it identifies the ties between individuals and then assesses the features of those individual ties and the network as a whole. This approach permits the analyst to investigate the configuration of teachers' social networks from the bottom up rather than assume in advance the locus of their relevant community. It also allows researchers to understand individual action in the context of larger structural configurations (Valente, 1995; Wasserman & Glaskiewicz, 1994).

Existing studies suggest that social capital has important consequences for knowledge development and diffusion of innovations. Coleman (1988) argues that social capital is important in the development of human capital—for example, children in families with more adult interaction have superior educational outcomes. Other researchers provide evidence that social capital influences a range of outcomes related to reform implementation, including increased problem solving, transfer of complex information, and diffusion of innovations (Adler & Kwon, 2002; Burkhardt & Brass, 1990; Frank et al., 2004; Gibbons, 2004; Penuel et al., in press; Uzzi, 1997; Uzzi & Lancaster, 2003). However, social capital theorists caution that there are negative outcomes associated with social capital as well. For example, Portes (1998) identifies such potential negative consequences as exclusion of outsiders, excess claims on group members, pressures for conformity, and downward leveling norms.

There are at least four dimensions of teachers' social networks that matter for the development of social capital: structure of ties, trust, access to expertise, and content of interaction. These dimensions can be viewed as sources of social capital (Adler & Kwon, 2002). That is, it is these features of teachers' social relations and the resources available through them that, when taken together, can create conditions that foster the creation of social capital (see Figure 1). Here, we review each of these dimensions in turn.

Structure of social networks. Studies in education have historically paid little attention to the structure of teachers' social relations (Penuel et al., in press). Yet a growing body of research suggests that the structure of networks is associated with a range of outcomes related to reform implementation. The specific quality and configuration of ties between individuals is important because it creates opportunities for social capital transactions (Burt, 1992; Coleman, 1988; Granovetter, 1973, 1982). One important dimension of the structure of social networks is the strength of ties between individuals. Tie strength is a function of emotional/social closeness and the frequency of interaction (Burt, 1992; Granovetter, 1973; Hansen, 1999; Marsden & Campbell, 1984). Recent work in organizational studies provides evidence that strong ties facilitate the transfer of tacit, sensitive, or complex knowledge (Hansen, 1999; Reagans & McEvily, 2003; Uzzi, 1997), joint problem solving (Uzzi,

1997), and the development of coordinated solutions (Uzzi, 1997). By contrast, weak ties have been found to play an important role in diffusion of ideas (Granovetter, 1982; Rogers, 1995), public information (Uzzi & Lancaster, 2003), and technical advice (Constant, Sproull, & Kiesler, 1996).

A second important dimension of the structure of social networks is called *tie span*. Ties that span social, subgroup, and organizational boundaries are important for accessing information that may not be available in one's proximate environment (Burt, 1992; Granovetter, 1973; Reagans & McEvily, 2003). Theoretically, span across "multiple knowledge pools" (Reagans & McEvily, 2003, p. 242) assists teachers in accessing information about a new approach to mathematics instruction, particularly when the approach is new to the grade level or school. This suggests that the degree to which a teacher's ties span different functional areas may provide her or him access to information crucial for implementation of a reform.

Trust. Bryk and Schneider (2002) conceptualize relational trust as an organizational property socially defined by the exchanges among members of a community and their reciprocal understandings about the obligations and expectations inherent in their organizational roles (e.g., principal, teacher). At the intrapersonal level, relational trust is rooted in the cognitive activity of discerning the intentions of others, which occurs within a set of interpersonal role relations formed by the structure of the school and the history of the school community (Bryk & Schneider, 2002).[1]

Trust is hypothesized to be an important attribute of teachers' social networks because it motivates one to share information in social interaction (Adler & Kwon, 2002). In schools, trust among teachers is a necessary condition for them to discuss the changes in practice demanded by ambitious instructional reform efforts (Tschannen-Moran & Hoy, 2000). In ongoing relationships within organizations, social networks can exert formal and informal control that encourages people to act in a trustworthy manner: There are incentives to develop a reputation of trustworthiness and so reap the benefits of trusting relationships (Coleman, 1990; Fukuyama, 1995; Putnam, 1993). At the tie level, trust enables the exchange of sensitive resources as well as finer-grained, tacit, and holistic information (Uzzi, 1997). At the organization level, trust enables organizational change by moderating the uncertainty and vulnerability that accompany change efforts, by reducing transaction costs involved in decision making, and by coordinating meaningful action (Bryk & Schneider, 2002).

Access to expertise. Social networks can be characterized by the "competencies and resources" available at their nodes (Adler & Kwon, 2002, p. 26). One primary way that individuals constitute resources within social networks is through their abilities and expertise. Some networks afford greater access to expertise than others do, depending on whom teachers are interacting with. In educational settings, leaders increasingly designate instructional coaches whose formal role is to facilitate the flow of expertise related to instructional improvement (Neufeld & Roper, 2003). Although only rarely taken into consideration in studies of social networks, a few studies have shown that access to expertise can be a statistically significant predictor of innovation use (Frank et al., 2004; Penuel et al., in press) and is associated with schoolwide implementation (Penuel et al., in press).

Content of interaction. By *content of interaction*, we refer to the substance of conversations in which actors in a social network engage. Much of the social network and social capital research pays little direct attention to the content of social interactions.[2] Yet there are two dimensions of the content of teachers' social interaction that studies suggest may matter for reform implementation: congruence and depth. Portes's work (1998) suggests that interaction in networks may result in pressures toward conformity and downward leveling norms, which may work against implementation, depending on the focus of the community. Indeed, prior research suggests that teacher community can impede reform if teachers' beliefs and values are not aligned with those of the reform (Coburn, 2001; Gallucci, 2003; Smylie & Evans, 2006). These studies provide evidence that teachers make decisions about implementation in conversations with their colleagues where divergent

views are manifest in the kinds of advice and interpretations of the approach. This suggests that the congruence is an important quality of interaction in social networks, and it acknowledges the possibility that not all interaction is positive for professional learning or reform implementation.

Second, most research on social networks focuses on their benefits for sharing information and disseminating innovations (see, e.g., Burkhardt & Brass, 1990; Frank & Zhao, 2004; Reagans & McEvily, 2003; Uzzi, 1997; Uzzi & Lancaster, 2003). However, implementing ambitious instructional approaches requires more than sharing information; it requires that teachers learn new things—about the curriculum itself, mathematics, instructional strategies, and student learning (Cohen & Hill, 2001; Guthrie, 1990; Remillard, 2005; Spillane, 2004). This suggests that the depth of interaction is an important feature of social networks because it may be key to providing teachers opportunities to learn in social interaction.

Factors That Influence Social Capital

Existing studies provide some insight into the factors that foster the development of these four sources of social capital. Social networks develop as individuals form network ties based on their perceptions of others, reaching out to those whom they see as having similar professional values (Coburn, 2001; Gibbons, 2004), who appear to occupy a similar structural position (e.g., having the same role or the same gender; Frank & Zhao, 2004; Hite, Williams, & Baugh, 2002), or whom they perceive as having expertise (Burkhardt & Brass, 1990; Penuel, Riel, Korbak, & Means, 2004; Spillane, Hallett, & Diamond, 2003). Other research emphasizes the role of prior relationships. Prior professional relationships and third-party referrals facilitate trust by reducing uncertainty and creating shared expectations for engagement (Larson, 1992; Uzzi, 1997). Finally, others emphasize the role of organizational conditions. These studies provide evidence that formal organizational structure—like grade levels and departments—shapes patterns of interaction (Adler & Kwon, 2002; Bidwell & Yasumoto, 1999; Gamoran, Gunter, & Williams, 2005; Penuel et al., 2004) and that school leadership plays a role by fostering an atmosphere of trust, shaping channels of communication, and communicating and enforcing norms of interaction (Bryk & Schneider, 2002; McLaughlin & Talbert, 2006; Smylie & Evans, 2006; Smylie & Hart, 1999; Sutherland, Smith, & Wallace, 2007).

However, we know little about the role of policy in influencing the development of social capital. With the exception of two studies that provide evidence that professional development opportunities can influence whom teachers interact with (Gamoran et al., 2005; Newman et al., 2000), we know little about how policy efforts to increase teacher professional community enable or constrain different dimensions of teachers' social networks. In addition, because few studies have paid attention to the content of interaction that happens in social networks, we know virtually nothing about the factors that influence depth and congruence. Here, we address these limitations.

Method

To investigate the role of policy in the nature and configuration of teachers' social networks, we draw on data from a longitudinal study funded by the National Science Foundation regarding the interaction among district reform strategies, human and social capital, and the implementation of ambitious mathematics curricula in two urban school districts. For this analysis, we employed an exploratory comparative case study design (Yin, 1994) guided by the following research questions: First, how does district policy influence teachers' social networks in mathematics, if at all? Second, what features of district policy appear to influence the four dimensions of teachers' social networks? The purpose of the analysis is to illuminate the relationship between district policies aimed at fostering collegial support and patterns of interaction among teachers. Our aim is not to generate findings that can be generalized to a broader population but rather to contribute to an emerging theory, derived from data, about the relationship between policy and teachers' social interactions that may form the basis for future investigation that explores causal relationships (National Research Council, 2002; Strauss & Corbin, 1994; Yin, 1994).

Sampling

We used purposive sampling (Maxwell, 2004; National Research Council, 2002; Strauss & Corbin, 1994) to strategically select school districts that would provide insight into the main phenomenon of interest to the larger study: districts implementing commercial curricula districtwide as part of broader efforts to improve teaching and learning in mathematics. Criteria for selecting the two focal districts included the following: First, they must be involved in scaling up commercial mathematics curriculum districtwide; second, they must be at the beginning of the scale-up process so that we could follow implementation over time; third, they must collect and be willing to provide access to student-level data linked to teachers, which was important for other facets of the projects; and, fourth, they must be willing to participate in the project. We identified 14 major urban districts that were involved in comprehensive approaches to scaling up commercial mathematics curricula districtwide, which was a common reform strategy at the time of study. Finding districts at the beginning stages of the scale-up process proved to be the most challenging criteria to satisfy. After phone interviews and visits to these sites, we selected two school districts—Greene School District[3] and Region Z (1 of 10 subdistricts in New York City)—because each had only recently embarked on districtwide scale-up of new standards-based elementary mathematics curriculum and met the other criteria for selection.

Region Z adopted *Everyday Mathematics*, and Greene School District adopted *Investigations in Data, Numbers, and Space.* It was the first time that either district did a districtwide adoption of a standards-based mathematics curriculum. Before Greene's implementation of *Investigations*, each school selected its own mathematics curriculum. The district provided training to a small subset of its teachers in cognitively guided instruction, a professional development program aimed at increasing teachers' understanding of the knowledge that students bring to the math learning process and how students connect that knowledge with formal concepts and operations (Carpenter, Fennema, Franke, Levi, & Empson, 1999). Overall, the approach is consistent with the *Investigations* curricula; but it was not a formally structured curriculum, and only a small portion of the district teachers were trained in the approach. Similarly, the implementation of *Everyday Math* was the first time that New York City implemented a single curricula for mathematics districtwide. The implementation coincided with a major change in district organization. Consolidated community school districts were restructured into 10 regions, and Region Z was composed of three former community school districts, two of which had a history of fostering traditional approaches to mathematics instruction.

Both Greene and Region Z launched extensive systems to support curriculum implementation, the centerpiece of which was the creation of school-level mathematics coaches in every school who were intended to be the vehicle for assisting teachers to learn to use the new curriculum. In Region Z, each school appointed a single full-time coach. In Greene, there were at least two mathematics coaches per site, each of whom acted as half-time coaches and half-time teachers. Before implementation, neither district had school-based mathematics coaches. Both districts also created new structures intended to encourage teachers to work with one another and to gain access to expertise about the curriculum. These structures included biweekly professional development at the school site (led by the coach), common prep periods for grade-level planning, and multiple districtwide professional development opportunities to provide access to expertise and cross-school networking.

Consistent with the exploratory theory-building purpose of our study, we used purposive sampling to select four elementary schools in each district ($n = 8$) on the basis of recommendations from the district directors of mathematics for schools with varying levels of professional community and teachers' expertise. Specifically, district leaders were asked to nominate schools where the faculty had relatively high and low levels of human and social capital, with *human capital* described as math instructional expertise and *social capital* described as interaction about mathematics instruction.[4] We conducted preliminary site visits for each nominated school, during which time we interviewed the principal, coaches, and key teachers about the nature of the social interaction in the school

as a whole and the level of expertise about mathematics. These visits confirmed that the four schools in each district nominated by the district mathematics coach varied in respect to their overall levels of interaction around mathematics and the degree to which there were teachers with instructional expertise in mathematics in the school.

All eight case study schools had demographic characteristics that were typical for the schools in their district. They all had a high percentage of students who qualified for free or reduced-price lunch (ranging from 73% to 99%), which was consistent with district averages (Greene average: 86%; Region Z average: 85%). Case study schools in Region Z had a majority of African American students, and schools in Greene had a majority of Latino students. Again, this was consistent with the demographic profile of the districts, although our case study schools tended to have somewhat smaller percentages of White students than district averages. Finally, as consistent with the demographics of their district, the four schools in Greene had a percentage of English-language learners higher than those in Region Z. See Appendix A for information about the case study schools and district averages.

In each school and on the basis of recommendations from the principal, we selected six focal teachers to represent the full range of grades and attitudes toward the new curriculum. We wanted to ensure that the teachers whom we selected held a range of attitudes toward the adopted curriculum, because we thought it possible that those who were supportive might have interactions in their social network different from those who were not, which might influence the content of interaction. Although we relied on the principals' recommendations to identify teachers' attitudes toward the curriculum, we were able to check these recommendations using several questions on a teacher survey administered later in the year.[5] (Details about the survey and its administration follow.) Survey results confirm that our sample included teachers with a range of attitudes toward the curriculum. However, our focal teachers' average was somewhat more negative toward the curriculum than the average for the school as a whole in three schools (School A, F, H), which might lead to lower-than-expected measures of congruence in these schools. See Appendix B for demographic information about the focal teachers and their attitudes about the new curriculum.

Data Collection

We conducted five interviews and six classroom observations per year with each focal teacher. We supplemented work with focal teachers with one to two interviews a year with the mathematics coaches ($n = 24$ interviews with 13 coaches: Region Z, $n = 4$; Greene, $n = 9$),[6] two interviews per year with the school principal ($n = 8$), one interview a year with six additional teachers (whom we called *nonfocal teachers*; $n = 48$), as well as observations of three to five occasions in each school where teachers interacted on matters of mathematics instruction (professional development, grade-level meetings, coaching sessions, etc.; $n = 30$).

A subset of this data collection was designed to investigate focal teachers' social networks. We took an egocentric approach to social network analysis. In it, the analyst maps networks that center on an individual or social unit (the ego; Wellman, 1993; Wellman & Berkowitz, 1988). To do this, we interviewed each focal teacher, using questions designed to find out whom the teachers talked with about mathematics instruction,[7] the frequency and content of their interactions, as well as why they talked with some people and not others.[8] We then analyzed these data and selected an additional six teachers to interview in each school (nonfocal teachers) who were part of focal teachers' social networks. During the subsequent visits to the schools, we interviewed these nonfocal teachers, using the same battery of social network questions supplemented with questions on their use of curriculum and background in mathematics. This approach allowed us to investigate in more depth the qualities of focal teachers' networks, including the location of expertise and content of interaction. We also devoted part of our interviews with school coaches and school principals to the same battery of social network questions that we asked teachers. We then supplemented the interviews by observing occasions where focal teachers interacted with colleagues identified in their social network interviews.

The strength of the egocentric approach is that rather than make assumptions about the nature and form of teachers' social networks, we took identification of the networks as an essential first step for empirical study. Because the analyst maps networks from the ground up using nominations solicited from the interviewees themselves, the egocentric approach does not assume that the locus of professional community is in formal structures, such as grade-level groups, or that it even exists within preexisting boundaries, such as the school (Carrasco, Hogan, Wellman, & Miller, 2006; Reagans & McEvily, 2003).[9] However, the limitation of the egocentric approach is that because we did not do social network analysis with all teachers in the school (as one would with sociocentric approaches to network analysis), we are not able to map the social network structure for the entire school, nor can we ascertain the degree to which focal teachers' social networks are representative of other teachers' networks in the school.

In addition to our school-level interviews and observations, our research collaborators administered a survey to all teachers in the case study schools (as well as teachers in 6 additional elementary schools in Region Z and 12 additional elementary schools in Greene) in spring 2005, the end of the second year of the study and the first full year of data collection in case study schools. The average response rate for case study schools was 80%. However, the survey, intended to serve another branch of the research project, was designed to support school-level analysis rather than analysis at the level of focal teachers' social networks, which was the main unit of analysis for the investigation discussed here. Thus, we were able to use only limited survey data to validate and extend our interview and observational data. Specifically, we used survey questions designed to investigate communication channels to generate our measures for tie strength and validate our interview data for tie span. All focal teachers responded to our survey in five of the eight focal schools; five out of six focal teachers responded in Schools A and B, and four out of six responded in School H.

Finally, to understand the nature of each district's scale-up strategy—in particular, the ways in which they envisioned and enacted professional development and structures to encourage professional community—we interviewed key district leadership (n = 17), observed professional development for teachers and coaches (n = 20), and collected and analyzed relevant district documents.

Data Analysis

For this article, we primarily drew on data from the 2004–2005 school year to develop egocentric networks. This was the second year of the study—but the first year that we engaged in the full protocol for social network analysis. We drew on data at the district level from 2003 to 2005 for our analysis of district strategy and professional development for coaches. We also drew on data from our first round of site visits to schools in spring 2004 for information on historical conditions of social interaction in case study schools.

Focal teachers' social networks were the key analytic unit for this study. We analyzed each teacher's social network according to the four dimensions outlined in our conceptual framework. To analyze the structure of teachers' social networks, we mapped each teacher's social network and analyzed the degree to which it spanned functional areas, including grade level, cross-grade level, school administrators, coaches, and those outside the school. To analyze tie strength, we drew on data from the teacher survey, which we validated and extended using interview data. Following convention in the field (Burt, 1992), we defined *tie strength* as a combination of frequency of interaction (ascertained through a survey question that asked, "How many times per month do you talk with these individuals?") and the degree to which a teacher felt close to members of his or her social networks (measured using a Likert-type scale: 1 = *not at all close*, 5 = *very close*).

We drew on the work of Bryk and Schneider (2002) to develop a set of indicators for interpersonal trust.[10] Indicators tapped into aspects of trust, including respect, personal regard, competence, and integrity in teachers' discernments of others. Whereas Bryk and Schneider examined relational trust at the organizational level, we measured trust at the level of focal teachers' social networks. To do so, we analyzed the degree to which focal teachers trusted each

member of their egocentric network. We then measured the percentage of individuals in a teacher's social network whom the focal teacher made positive statements of trust about.

To analyze access to expertise, we assessed the degree to which individuals in a teacher's social network had participated in prior professional learning opportunities related to mathematics (see Appendix C for definitions of *low*, *medium*, and *high expertise*).[11] For example, an individual was considered to have high expertise if he or she had participated in four or more intensive professional development experiences. *Intensive professional development* was defined as sustained learning opportunities that last more than a week (e.g., summer institutes) or in-depth coaching. This definition did not include one-shot workshops or short-term experiences. Alternatively, someone with an undergraduate math major or specialization in mathematics education in graduate work accompanied by two or more intensive professional development experiences was considered to have a high level of expertise. After evaluating the expertise of each individual in a focal teacher's social network, we then determined focal teachers' access to expertise in the network as a whole. If there were one or more individuals with high expertise in the network, we classified the network as affording access to high expertise. Similarly, if one or more individuals in a focal teacher's network had moderate expertise but no one had high expertise, we identified the network as affording access to moderate expertise.

Finally, we analyzed two dimensions of the content of interaction: congruence and depth. To do this analysis, we identified 783 instances from our data where focal teachers were interacting with others in their social networks. We then analyzed the content of the interactions for depth and congruence. For congruence, we developed separate indicators for each curriculum based on an in-depth analysis of the curriculum conducted by other members of the research team (Stein & Kim, in press). For example, *Everyday Mathematics* relies on a spiral structure where lessons that happen later in the sequence depend on material covered earlier. Because of this design, conversations where teachers gave one another advice about skipping particular lessons were deemed incongruent. In contrast, *Investigations* has a modular design. The curriculum does not require that teachers use all units, and there is flexibility in the order that units are employed. Because of this different design, conversations where teachers give one another advice about skipping a unit would not be considered incongruent in Greene. We coded 676 interactions where we had enough information to allow us to code for congruence. (See Appendix C for complete definitions of congruence for each curriculum.) We drew on our previous work (Coburn, 2003) to develop criteria for depth of interaction. Interaction was judged to be at low depth when it focused on surface structures and procedures, such as sharing materials, classroom organization, pacing, and how to use the curriculum. Interaction was judged to be at high depth when it addressed underlying pedagogical principles of the approach, the nature of the mathematics, and how students learn. We analyzed 758 interactions for which we had enough information to assess depth. (See Appendix C for complete definitions of depth.)

Once we analyzed the dimensions of each focal teacher's social networks, we used a series of matrix displays (Miles & Huberman, 1994) to compare characteristics of social networks across schools in an effort to identify school-level factors contributing to the development of social networks. For example, we created matrices examining the depth of interaction at the focal teacher level, tallying the number of interactions that each focal teacher had at different levels of depth (low, moderate, high) with individuals in their networks from different functional areas (coach, teachers at grade level, principal, etc.). We then aggregated counts for each level of depth to examine patterns among schools. We followed similar procedures for each dimension.

Once we created matrices at the school level, it became apparent that there were important differences between districts. Therefore, we compared social networks across districts to identify factors associated with the school system, the curriculum itself, and the district's approach to fostering implementation (reform strategy) that may have shaped the development of teachers' social networks. To rule out the possibility that differences among schools and between districts were due to chance, we performed appropriate statistical tests. We used one-way analyses of

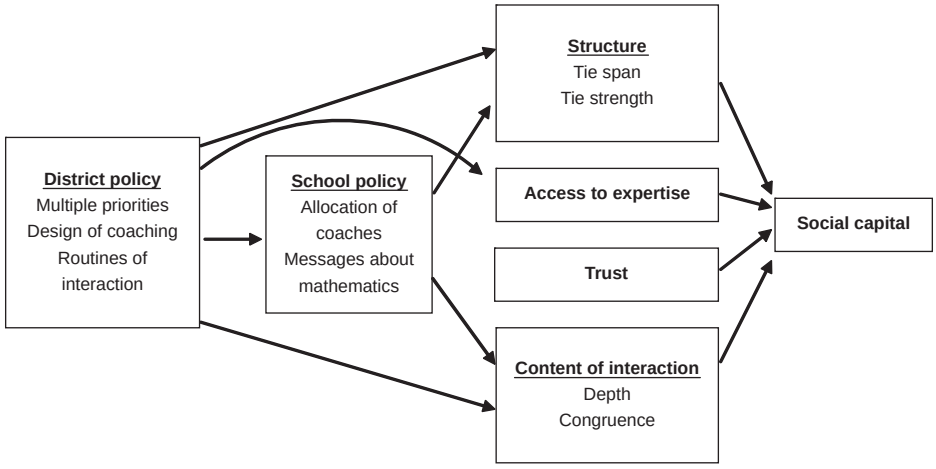

FIGURE 2. *Relationship between school/district policy and sources of social capital.*

variance for numerical dependent variables and chi-square tests for testing the relationship between two categorical variables. When expected cell counts were below 5 for chi-square tests, we verified the results with other tests, such as the Fisher exact test.

District Policy and Teachers' Social Networks

Both Greene School District and Region Z invested heavily in creating structures to encourage interaction between teachers and experienced others as a way to support teachers' efforts to learn and implement new ambitious mathematics curricula. Our data suggest that these efforts did in fact influence the nature and quality of teachers' social relations—but not always in ways anticipated by district leaders. As illustrated in Figure 2, the development of the coach role appeared to influence the structure of teachers' social network, given that most teachers in the study nominated the coach as someone to whom they reached out to talk about mathematics. However, differences in the designs of the coaching initiative and the presence of multiple competing initiatives in one district meant that teachers in that district did not interact with the coach with frequency or closeness and that when they did interact, the interaction did not afford access to expertise.

Furthermore, we uncovered a role for district policy in teachers' social interaction that has not received any attention in either the scholarly literature or the reform literature. We found that district-developed routines of interaction diffused through social networks, shaping what and how teachers talked with one another about mathematics and influencing depth of interaction. Finally, we found that school leaders mediated district policy. By making decisions about how to allocate coaching and meeting resources and by promoting their own messages about appropriate ways to use the mathematics curricula, school leaders shaped the structure of teachers' networks—especially, tie strength—as well as the depth and congruence of interaction that teachers had within these networks. In the sections to follow, we discuss the relationship between district policy and teachers' social networks. We then turn our attention to the role of school leaders. We close by discussing the absence of district and school policy influence on the degree to which teachers trusted others in their social network.

Role of District Policy

There were three striking and statistically significant differences in the nature of teachers' social networks in Greene School District, as compared to Region Z. First, teachers in Greene were more likely to have higher tie strength with individuals in their social networks, particularly with their coaches. Sixty percent of teachers in Greene had an average of moderate or high tie

strength, compared with only 31% of teachers in Region Z. Furthermore, 96% of focal teachers in Region Z had low tie strength with the coaches, compared to only 38% of Greene, $\chi^2(2, N = 42) = 13.82$, $p < .05$. Second, all focal teachers in Greene had access to moderate or high expertise in their networks, whereas only 44% of focal teachers in Region Z had access to moderate expertise and none had access to high, $\chi^2(2, N = 38) = 35.69$, $p < .001$. Third, there was a substantial difference in depth of interaction. On average, focal teachers in Greene had 56% of their interactions at moderate or high depth, whereas focal teachers in Region Z had an average of only 17%: The proportion of interactions at moderate or high depth varied significantly between districts, $F(1, 46) = 37.40$, $p < .001$.

In this section, we argue that these differences can be explained by the manner in which the two districts went about scaling up the mathematics curriculum. Specifically, we draw on interview and observational data to argue that the presence or absence of competing priorities, hiring and training of coaches, and the creation of routines of interaction played a role in whom teachers interacted with, with what frequency, and what they talked about when they reached out to others in their mathematics networks.

Coaching initiative increases tie span. District scale-up policy played a role in the structure of focal teachers' social networks through the creation of the position of school-based mathematics coach. The creation of the on-site coach was the centerpiece of the mathematics initiative in both districts, establishing a role that was entirely new for seven of our eight case study schools. Yet, in spite of the newness, the majority of teachers in both districts—45 out of 48—nominated the mathematics coach as a member of their social network. This would not have been possible even 2 years before, because the position did not exist; in fact, only 1 of the 45 teachers reported that she interacted with the person in the position of coach before the creation of the role. Because teachers reached out to the coaches and included them in their social network, the district policy decision establishing school-level coaches influenced the degree to which teachers' social networks spanned functional areas of the school. At least theoretically, this increase in tie span should create greater access to information about the new curricula for teachers.

Coach selection practices influence access to expertise. However, at the same time that the creation of the coach role increased tie span for focal teachers, different approaches to coach selection and preparation in the two districts influenced access to expertise in teachers' social networks in contrasting ways. Coaches were the main source of expertise for focal teachers in Greene, given that all the coaches in the case study schools had either moderate or high expertise whereas the majority of teachers had low expertise. In contrast, only one coach in Region Z had moderate expertise; the other three had low expertise, as did the majority of teachers in the schools. As a result, all focal teachers in Greene had access to moderate or high expertise in their social networks, whereas only 9 of 18 teachers for whom we have information in Region Z had access to moderate expertise and none had access to high.[12]

Part of the disparity in coach expertise had to do with hiring and preparation practices in the districts. In Greene, coaches were hired at the school level using a set of criteria developed by the director of mathematics that specified required training and background. To satisfy the criteria, principals mainly drew on the district's existing teacher leaders in mathematics—those who had been involved in mathematics professional development activities related to cognitively guided instruction through the district's systemic reform initiative for the past several years and were active in district-level mathematics activities. The Greene coaches then took two in-depth courses on the *Investigations* curriculum and the mathematics underlying it, before becoming coaches. They were supported in their ongoing coaching by once-monthly day-long coach professional development and quarterly visits from the district director of mathematics, who observed classrooms alongside coaches and discussed strategies for helping teachers improve their instruction.

In Region Z, the mathematics director selected coaches the first year of implementation. However, in the second year, the responsibility for selecting coaches shifted to the school principal, and in the absence of any guidance

from the district and a limited number of qualified teachers in the region overall, school principals did not choose teachers with a high level of mathematics expertise. In one school—School C—the principal hired a former first-grade teacher in the school to be the coach. This teacher, who described herself as being more interested in literacy than math, had taken little professional development in mathematics before securing the coaching position. Similarly, two other principals in Region Z selected teachers who had been resource teachers and whose primary responsibilities had been working with small groups of students in pullout settings on remedial mathematics. These coaches had no background in the curriculum and little prior professional development in mathematics teaching and learning. Whereas three of the four Region Z coaches attended weekly meetings with the region, only two had intensive professional development in the curriculum or the mathematical ideas underlying it before assuming the position. Furthermore, coaches only rarely received on-site visits from the mathematics director, who had the responsibility of supervising coaches in 64 elementary and K–8 schools, precluding on-site professional development for coaches of the sort provided by Greene School District. As a result, the presence of coaches in focal teachers' social networks increased teachers' access to mathematics expertise in Greene School District but not, for the most part, in Region Z.

Multiple initiatives and design of coaching influence tie strength. The design of the coaching initiatives and the presence of multiple competing initiatives in Region Z appear to have fostered much higher tie strength in Greene than in Region Z, especially between focal teachers and coaches. Tie strength is generally conceptualized as the product of frequency of interaction and social closeness. It is important as a source of social capital because it facilitates problem solving and the transfer of tacit, complex, or fine-grained information (Hansen, 1999; Uzzi, 1997; Uzzi & Lancaster, 2003).

As was the case with coach hiring and selection, Region Z and Greene differed in the degree of specification for what coaches should do at the school site. In Greene, the district director of mathematics made it clear that all coaches were to participate in weekly classroom coaching with teachers, meet with teachers in their grade-level groups, and run the biweekly after-school professional development focused on mathematics. Furthermore, district mathematics leadership communicated this message in monthly professional development meetings for mathematics leadership teams attended by coaches, assistant principals, and principals from each school. Coaches in all four schools in Greene engaged in systematic classroom coaching (although the number of teachers whom they worked with varied quite a bit), met with teachers in grade-level groups, and provided biweekly professional development to teachers focused on mathematics. For example, a teacher at School E described how she worked with her coach:

> Basically, [the coach] observes me for one day a week, and then we go back the next day and we talk about the lesson so she can specifically give me feedback on what she saw that I was doing well and what she thinks I need to keep working on. So she is going to give me specific feedback on the lesson and if I need to do anything differently, if she thinks that [students] understand it or not, because maybe she is seeing something that I don't see.

All teachers in the case study schools in Greene interacted with coaches at least two times a month—and more if they were being actively coached. Thus, it is no surprise that 14 out of 22 focal teachers in Greene reported that they had moderate or high tie strength with the coaches.

In contrast, whereas mathematics leaders in Region Z also expected that coaches would participate in classroom coaching and lead bimonthly professional development in mathematics, they were not as clear about articulating what classroom coaching entailed. School principals had few connections to district- and region-level mathematics leaders, who were able to get on the agenda for principals' meetings only for informational presentations about the curriculum once or twice a school year. As a result, school leaders in Region Z had more discretion and less guidance about how to structure the day-to-day duties of their school-based coaches.

Principals in Region Z used coaches in ways that spanned from primarily having them work

with students in small group settings and spending little time working directly with teachers (except as a source of supplies), to having them work intensively with a small number of teachers to provide demonstration lessons, observe classrooms, and provide feedback. Schools in Region Z also varied in the degree to which principals asked coaches to meet with teachers in grade-level groups. It was also common for principals to pull coaches away from coaching duties to address a range of other pressing needs. One coach described how he was often pulled away from his regular coaching duties by the school leadership: "I have a regular schedule but what happens is that Ms. Norman [assistant principal] or Ms. Perry [principal] or somebody will encounter a big problem somewhere that needs to be dealt with." He went on to explain how he ended up spending much of his time that year helping one teacher with her classroom management (she started midyear) and working directly with students who failed an interim assessment.

In addition to the degree of specificity in coaching design, competing initiatives in Region Z made it difficult for teachers to interact with coaches and one another with frequency and closeness. The year that New York City initiated *Everyday Mathematics*, it also initiated a new districtwide literacy program. Both of these initiatives competed for teachers' scarce time and attention, and mathematics often lost out. Although the district required that schools alternate after-school professional development between literacy and mathematics and use one common prep period a week for mathematics, all four schools in Region Z more often used this time for literacy than for mathematics. For example, in School C, teachers reported in May that they had only had two after-school professional development sessions on mathematics all year. Similarly, the coach in School B explained that teachers did not often talk about mathematics during their joint prep periods: "Literacy. They get first dibs on everything. So, I used to be able to go to their common preps . . . but I don't even get that opportunity anymore because their common preps are often consumed by some literacy thing." Interestingly, the pattern of using time for literacy that was intended for mathematics occurred not only in schools whose reading test scores were lower than their mathematics scores (where one might expect a reallocation of resources toward literacy) but also in schools where the mathematics scores were lower than reading scores. Given the fact that school leaders in Region Z frequently used coaches for reasons other than classroom coaching and that competition for teachers' time meant that schools did not have regular opportunities for interaction about mathematics, it is no surprise that only two focal teachers reported having moderate tie strength with the coach and that no teacher reported having high tie strength. This finding suggests that district policies resulted in relatively infrequent interactions between teachers and coaches in Region Z.

Routines of interaction influence depth. Finally, the design of the coaching initiative appears to have influenced depth of interaction in focal teachers' social networks. Recall that focal teachers in Greene had an average of 56% of their interactions at moderate or high depth, compared to 17% in Region Z. This contrast is striking given that historical data suggest that modal interaction among focal teachers in all eight schools before 2004–2005 was at a predominantly low level of depth.[13] Although our data are not comprehensive, only 13% of interactions for focal teachers in Greene and 11% of interactions for focal teachers in Region Z were at a moderate level of depth. These percentages are consistent with research on teacher professional community that describes typical interaction characterized by swapping stories, sharing materials, and providing discrete bits of information or advice (Little, 1990; Lortie, 1975; McLaughlin & Talbert, 2001)—all of which would be considered low depth in our coding scheme. This finding suggests that focal teachers in Greene have experienced a large increase in the depth of interaction since the inauguration of the mathematics initiative, although there has been a small decrease in depth for those in Region Z during the same time. In this section, we argue that this disparity was due to the two districts' design for professional development that emphasized different routines of interaction and that coaches, in turn, carried to teachers. When enacted in schools, routines of interaction developed by each district led to interactions in teachers' social networks of varying degrees of depth.

TABLE 1
Presence of Routines of Interaction in District Professional Development and in Teacher Social Networks

Routines for interaction	Rank order of prevalence in district professional development		Percentage of interactions in schools (*n*)		Average depth
	Greene	Region Z	Greene	Region Z	
Task analysis	1	5	10.8 (48)	1.6 (5)	Moderate
Analyzing student strategies	2	N/A	16.7 (74)	2.2 (7)	Moderate
Structured reflection on practice	3	N/A	7.0 (31)	0.0 (0)	Moderate
Doing math problems together—emphasis on how-to	4	2	0.4 (2)	8.3 (26)	Low
Explanation (how to use the curriculum)	5	1	4.7 (21)	25.7 (81)	Low
Mapping activities	N/A	3	7.2 (32)	3.5 (11)	Low
Demonstration lessons	N/A	4	0.9 (4)	1.9 (6)	Moderate
Other			52.1 (231)	56.8 (179)	Low

Note. $n = 443$ interactions in Greene; $n = 315$ interactions in Region Z.

To make this argument, we begin by analyzing interviews with district mathematics leaders and observations of professional development for coaches in both districts. We identified a series of distinct routines of interaction that were employed with coaches during professional development and which coaches, in turn, were asked to use with teachers in schools. We define *routines of interaction* as routines intended to guide conversation between adults on matters of instruction. Following Feldman and Pentland (2003), we define *routines* as "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors" (p. 95). We then show that the routines of interaction that characterized district professional development became a prominent feature of interaction in focal teachers' networks in ways that influenced the depth of their interactions.

The two districts had strikingly different approaches to professional development for coaches. As illustrated in Table 1, district leaders in Greene engaged coaches in such activities as task analysis, investigations of student problem-solving strategies, and structured reflection on their practice. Each activity involved a distinct routine where the leader of professional development led coaches through a predictable set of interactions, asking a predictable set of questions to guide discussion. For example, coaches in Greene spent a lot of time in district professional development doing task analysis in various forms. In this routine, the facilitator asked coaches to do a mathematics problem together from the *Investigations* curriculum or watch a video of a lesson. Facilitators would ask, "Where's the mathematics here?" or "What is the objective?" Coaches then analyzed the mathematical task to uncover the underlying mathematics that students would need to solve the problem, which was followed by a whole group debrief. For example, during one on-site professional development meeting with coaches and school leaders at School E, we saw the district mathematics director repeatedly lead the school leadership team through this routine. The group observed a series of mathematics classrooms. After each observation, the group gathered in the hallway, and the district mathematics director asked, "What was the objective of that lesson?" The coaches and school leaders then analyzed the mathematics that the lesson addressed, and they discussed (a) the degree to which the teacher's instruction focused on the mathematical ideas, (b) the ways that students were grasping these ideas, and (c) the next steps for coaching the teacher. We also saw this routine over and over in districtwide coach professional development.

In another example in Greene, coaches were frequently asked to first analyze what strategies children were using to solve mathematics problems and then brainstorm ways to build on and

extend children's strategies. In this routine, the facilitator asked coaches to view a video of a classroom or analyze a piece of student work to identify the strategies that children were using for solving the problems. For example, the following excerpt from field notes illustrates this routine, as observed in a professional development session for coaches in Greene:

> When I came to the art room where the professional development meeting was held, the math coaches were watching a video clip prepared by Laverne [professional development provider]. In that video clip, Laverne was interviewing with a second grader. She asked questions about two-digit addition and subtraction (e.g., 28 + 24, 34 – 16). The student was answering the questions using interlocking cubes. After the video clip, Laverne wanted math coaches to talk in their group about the student's strategies displayed in the video clip. Participants discussed in their groups about the student's strategies for two-digit addition and subtraction. . . . Then the facilitator asked the participants about the student's way of solving the subtraction problem for 34 – 16.

In contrast, the most common routines of interaction that we observed in professional development for coaches in Region Z were as follows: explanation about how to use the curricula; working on mathematics problems for the purposes of learning how to teach the lessons; and mapping activities where coaches were asked to draw connections among the curriculum, the state standards, the pacing guide, and the assessments. For example, during one half-day professional development for coaches in the region, the professional developer began by explaining how *Everyday Mathematics* was organized, then proceeded to a discussion of the role of the games in an *Everyday Mathematics* lesson, followed by an explanation of how to use the math journals, culminating with a group discussion of how to do mental math (a key component of an *Everyday Mathematics* lesson). As was the case in Greene, the professional development in Region Z sometimes involved coaches doing activities from the curriculum—especially, playing some of the math games. In contrast to that of Greene, the routine emphasized how the games worked and how they were used in the context of the rest of the lesson, rather than the mathematical ideas involved.

Distinct routines of interaction from district professional development—many of which depart substantially from modal teacher interaction—became important features of interaction in teachers' social networks in both districts as coaches used these routines in their interactions with teachers. As can be seen in Table 1, coach professional development in Greene emphasized task analysis, analyzing student strategies for problem solving, and structured reflection on practice. And, indeed, these routines of interaction were prominent features of teachers' interaction with others in their networks. For example, one coach in School E described a recent meeting with the teacher where they analyzed student strategies for solving problems:

> One of the things that [we] have been working on is subtraction strategies. And one of the things we talked about last week was, do the kids really understand what they are doing? Do they really have some numerical reasoning there, or are they just following a process to get an answer? . . . And how do they know their kids really understand what subtraction is, and how are we going to get to that? Because some kids are trying to apply a process and are not getting to the right answer. And why is that? Why are they using this process that doesn't make sense, and why don't they know their answer doesn't make sense? So we looked at some student work and talked about some stuff about that.

In contrast, as illustrated in Table 1, coach professional development in Region Z emphasized explanation, doing math problems together as a way to understand how to do the activities, and mapping activities. And, indeed, just over 25% of interactions around mathematics for focal teachers in Region Z involved explanations about the logic of the curriculum and how to do a particular activity. For example, one teacher in School B described a recent interaction with the coach that involved the routine of explanation:

> We talked about, like, the math message and the mental math and how to coordinate the two and that we should be linking the message to the initial onset of the mini lesson and how those two are connected and that that would get the children eventually into their individual work and that we should connect them and that the math messages is separated from the mental math after it's done until we go back to it and use that as a lead in for the lesson.

In addition to explanation, other routines of interaction that were emphasized in Region Z's

professional development were prominent in teachers' interaction (see Table 1).

It is important to note that these routines, though most prevalent in coaches' interactions with teachers, also appeared in focal teachers' interactions with other teachers in their social networks when the coach was not present. This was especially the case in Greene. Thus, whereas the coach was present for 85% of the 48 interactions involving task analysis, 10% of all task analysis took place when teachers interacted on their own with other teachers in their social networks. Similarly, whereas the coach was present for 55% of 74 interactions that involved analyzing the strategies students were using for solving problems, just over 40% of those interactions involved teachers talking with other teachers. This phenomenon was present in Region Z but to a lesser extent. Five percent of 81 instances of explanation about how to use the curriculum and nearly 4% of 26 instances where teachers did mathematics problems together as a way to figure out how to do them in their classroom took place as focal teachers talked with their colleagues without the coach present.

This analysis of routines is pertinent to the question of depth of interaction because different routines tended to result in different levels of depth. As shown in the far right column in Table 1, most of the routines of interaction emphasized by district professional development for coaches in Greene—task analysis, analyzing student strategies, and structured reflection—resulted in interactions in teachers' social networks that were, on average, at a moderate degree of depth. In contrast, most of the routines of interaction emphasized in Region Z—explanation, doing mathematics problems to learn how to do them, and mapping activities—resulted in interactions at a low degree of depth. Because these routines of interaction accounted for nearly 50% of interactions in Greene and Region Z,[14] district choices about what to emphasize in professional development with coaches played an important role in the disparity of depth of interaction for teachers in Greene versus Region Z.

Finally, routines of interaction appear to influence depth of interaction regardless of the coach's expertise. In Region Z, the one coach with moderate expertise actually had lower depth of interaction with teachers than that of fellow coaches with low expertise (90% of interaction with the moderate expertise coach were at low depth, compared to 86%, 64%, and 56% for low-expertise coaches). Similarly, there was little difference in depth between coaches in Greene with moderate versus high expertise.

All of this suggests that more than just information can flow along social networks. In this case, coaches acted as bridges between districts and schools, bringing routines of interaction into teachers' social networks, which then diffused among teachers. These routines of interaction were important because they had the potential to create conditions for interaction that, in some cases, pushed interactions toward greater depth. It further suggests that it is indeed possible to intervene to increase the depth of interaction in teachers' social networks. Efforts in Greene encouraged teachers to talk about mathematics instruction in ways that were more detailed, more focused on issues of student learning, and more grounded in real and complex situations in their classroom. And our findings suggest that district interventions are not dependent on coach expertise, because well-crafted routines of interaction encouraged higher depth interaction despite variation in coach expertise.

Policy Initiatives Mediated at the School Level

Within these broad patterns by district, there was between-school variability in key dimensions of teachers' social networks—especially, depth and congruence. Prior research suggests that school leaders mediate state and district policy as they bring policy messages to teachers (Coburn, 2001, 2005; Spillane et al., 2002). Our research suggests that this pattern holds with policy initiatives intended to foster social relations as well. Specifically, school leaders played a role in fostering depth through the way that they allocated coaching resources. They—along with coaches—also influenced the degree of incongruent interactions by promoting messages that were inconsistent with district aims.

Allocation of coach resources influences depth. In addition to the district-level differences in depth of interaction, there were statistically significant differences between schools: The proportion of

TABLE 2
Depth of Interaction, by School

	% (*n*)		
District	Low	Moderate	High
Region Z			
School A	93.8 (45)	6.2 (3)	0.0 (0)
School B	82.9 (63)	17.1 (13)	0.0 (0)
School C	81.7 (85)	18.3 (19)	0.0 (0)
School D	78.2 (68)	20.7 (18)	1.1 (1)
Greene			
School E	59.3 (73)	32.5 (40)	8.1 (10)
School F	52.3 (46)	37.5 (33)	10.2 (9)
School G	58.0 (65)	33.9 (38)	8.0 (9)
School H	39.2 (47)	54.2 (65)	6.7 (8)

Note. $n = 315$ interactions in Region Z; $n = 443$ interactions in Greene.

interactions at moderate or high depth varied significantly among schools, $F(7, 40) = 8.23$, $p < .001$. Here, we argue that between-school differences in depth—as illustrated in Table 2—were related to the way that school leaders configured coaches' work with teachers.

As described in the discussion of tie strength, there were differences in the degree to which districts specified how coaches were to be used at school sites. In Region Z, school leadership had quite a bit of latitude with how they asked coaches to spend their time. Although there was less latitude in Greene—given that all coaches were involved in weekly classroom coaching with teachers and met with teachers in their grade-level groups—principals did make different decisions regarding the number of coaches to hire and the number of teachers that each coach worked with. For example, School E had 2 half-time coaches for 39 classroom teachers, which was not enough to meet the needs of the school. Only one third of focal teachers (and 30% of the teachers in the school overall) received active coaching. By comparison, School H had 3 coaches for 37 classroom teachers, which provided more access to coaching resources. Every focal teacher in School H (and 75% of the school overall) was actively coached.

School leaders' decisions about allocating coaching resources were consequential for depth because teachers who were actively coached—where coaches observed their classroom and provided feedback on a regular basis—had a greater percentage of interaction at moderate or high depth, when compared to those who were not (see Table 3). This happened for two reasons. First, coaches tended to draw on routines of interaction fostered by district professional development that supported depth of interaction during active coaching with teachers. But teachers who were actively coached also tended to have greater depth of interaction with their colleagues even when the coach was not around because they, too, were more likely than noncoached teachers to draw on district-developed routines of interaction. As illustrated in Table 3, those teachers who were actively coached had much deeper conversations with other teachers in their network. All this suggests that school leaders' decisions that increased or decreased the number of teachers who were actively coached influenced the overall degree of depth of interaction at a school.

School leaders influence congruence. There was also a difference in levels of congruence between the eight schools, as illustrated in Table 4. The proportion of incongruent interactions in focal teachers' social networks was significantly different among schools, $F(7, 40) = 5.55$, $p < .001$. School leaders influenced the level of incongruent talk as well as the content. By engaging in incongruent talk with teachers, school leaders influenced the level of incongruence in focal teachers' networks. And by promoting messages about the curriculum that influenced how teachers

TABLE 3
Depth of Interaction, by Coaching Intensity

	Percentage (*n*) of interaction at moderate or high depth			
	Region Z		Greene	
Coached	In entire network	Among teachers	In entire network	Among teachers
Actively	26.0 (32)	25.0 (10)	51.6 (169)	35.0 (41)
Not actively	11.4 (22)	2.7 (2)	38.4 (43)	21.0 (12)

Note. Region Z: $n = 315$ interactions in entire network, $n = 113$ interactions among teachers; Greene: $n = 443$ interactions in entire network, $n = 175$ interactions among teachers.

TABLE 4
Congruence of Interaction, by School

	% (*n*)	
School	Congruent	Not congruent
Region Z		
School A	48.9 (23)	51.1 (24)
School B	83.1 (59)	16.9 (12)
School C	87.1 (88)	12.9 (13)
School D	82.0 (41)	18.0 (9)
Greene		
School E	75.9 (85)	24.1 (27)
School F	82.4 (70)	17.6 (15)
School G	73.6 (78)	26.4 (28)
School H	93.3 (97)	6.7 (7)

Note. $n = 269$ interactions for Region Z, $n = 407$ interactions for Greene.

talked about the curriculum, they influenced the content of incongruent talk. In this way, school leaders mediated district policy by shaping the messages about the curriculum that became salient at their school.

First, principals, assistant principals, and coaches were a key source of incongruent interaction with teachers. Together, coaches and school leaders accounted for 65% of incongruent interaction in Greene and 58% of incongruent interaction in Region Z. For example, the principal and early childhood coordinator in School A accounted for just over 60% of all incongruent talk in focal teachers' networks in School A, telling teachers that they should focus only on the secure goals in *Everyday Mathematics*, rather than on all the goals, and instructing them to skip sections of each lesson. For example, one teacher in School A described the "working lunches" that her grade-level group had with the principal and the assistant principal:

> People come in and ask, "Well, do you really need all this stuff for this lesson?" And they tell us that some things you don't necessarily need to do the complete lesson or different parts you can kind of not use 'cause it's too much.

But beyond their influence on the level of incongruent interaction in the school, school leaders in both districts also influenced the content of that interaction. That is, the incongruent messages that principals and coaches promoted in a given school tended to become key features of teachers' conversations with one another. For example, in School G, the principal placed a strong emphasis on test preparation strategies that were not congruent with the aims of the *Investigation* curriculum. One teacher at School G recounted her surprise when her principal encouraged them to use test preparation materials to supplement *Investigations*:

> I remember in a meeting the first time our principal said, "Yes, I do expect you to teach the TERC program, but you can supplement whatever you want." My mouth dropped, and my eyes went wide, and I looked over, and [the math coach] had almost the exact same look on her face as I did.

Given the principal's emphasis on test preparation, it is perhaps no surprise that 60% of all incongruent talk in School G involved teachers' discussing strategies for test preparation. In contrast, school leaders in School F emphasized moving students to more efficient strategies for problem solving, something that is not really

TABLE 5
Teachers' Level of Trust by School

School	Percentage of individuals trusted in social network (number of teachers)				Average trust per school (%)
	0–25%	26–50%	51–75%	76–100%	
Region Z					
School A	2	2	1	1	20
School B	3	2	1	0	27
School C	3	2	1	0	27
School D	2	3	1	0	34
Greene					
School E	3	1	1	1	40
School F	2	2	1	1	43
School G	4	2	0	0	20
School H	2	2	1	1	43

Note. $n = 48$ teachers.

supported by the *Investigations* curriculum. For example, in one professional development session that we observed, a coach asked a focal teacher who was looking at student work, "What would your next step be with these children? How could you move their understanding along so that they become more efficient?" This question precipitated a discussion of several strategies for helping students become more efficient problem solvers. As was the case in School G, the messages emphasized by school leaders became the predominant incongruent messages among teachers. Sixty percent of the incongruent messages among teachers in School F were about moving students to more efficient strategies for problem solving, but only 4% of incongruent interactions focused on test prep, which was not a priority for this principal. In these two schools and the other six in our sample, the substance of incongruent talk among teachers was consistent with the focus of incongruent messages emphasized by the school leadership.

Social Policy and Trust

Finally, we must discuss the distinct absence of a clear district or school influence on the degree to which teachers trusted others in their social networks. As illustrated in Table 5, there were greater differences within schools than between schools in the degree to which focal teachers trusted others in their social networks. For example, in School A, two teachers did not trust anyone, whereas one teacher trusted 60% of her network and another trusted 100%. Similarly, there was no statistically significant difference between districts or among schools in the proportion of people in a network that teachers trusted: between districts, $F(1, 46) = 0.27$, $p = .609$; among schools, $F(1, 46) = 0.65$, $p = .714$. This is surprising given that prior research has suggested that school-level factors—especially, principal leadership—can play a strong influence on levels of trust within a school (Bryk & Schneider, 2002; McLaughlin & Talbert, 2006; Smylie & Hart, 1999).[15] Yet in our study, factors outside the purview of policy were more influential for the degree to which focal teachers trusted others in their networks. In particular, teachers' prior professional relations and proximity were important.

Prior professional relations. Teachers were more likely to trust those in their social networks if they had prior professional relationships with them. Research outside of education suggests that prior social relationships play a powerful role in the degree to which individuals seek out and trust others (Larson, 1992; Uzzi, 1997). Indeed, nearly two thirds of teachers mentioned prior professional relationships as a key reason that they sought others out. For example, one kindergarten teacher gave the following explanation for why she interacted with

several second-grade teachers in her school: "I talk with them because I taught second grade last year, and they are some of my closest colleagues in the building." These prior relationships also fostered trust. Teachers were much more likely to trust individuals with whom they had prior relationships than they were to trust others in their social networks. On average, focal teachers trusted 54% of the individuals in their social networks with whom they had prior professional relationships, compared to 32% overall. Teachers who cited prior professional relationships as a reason for reaching out to teachers in their network were evenly distributed throughout the schools in our sample, with one exception: School G, which had one of the lowest overall levels of trust (teachers trusted only 20% of others in their social networks), had the fewest teachers who reported reaching out to others on the basis of prior professional relationships. This school also had the highest turnover rate of any school in our sample—nearly 50% of teachers were new to the school in the previous 3 years—which may account for the absence of prior professional relationships in teachers' social networks.

Proximity. Teachers also tended to reach out to those who were physically close by, which appeared to influence trust. Just over half of all focal teachers—25 out of the 48—reported that they went to individuals to talk about mathematics because of their proximity. For example, one teacher in Greene reported that she interacted with the coach when she ran into her in the copy room. Multiple teachers mentioned interacting most with the teacher next door, the teacher with whom they did bus duty, or the teacher with whom they carpooled. When asked why she talks with one colleague about mathematics, a teacher at School E replied, "Because she is next door. So when I think of it off the top of my head, I will just open my door and just ask her real quickly, and I don't have to wait until I see her at lunch." The importance of proximity is not surprising given the fact that most teachers have little time during the day when they are not in the classroom with their children, and it echoes findings about social networks in the broader literature (McPherson, Smith-Lovin, & Cook, 2001; Mok, Wellman, & Basu, in press). What is surprising is that when teachers interacted with others by virtue of proximity, they tended to trust them. Focal teachers trusted 53% of the individuals whom they interacted with because of their proximity, compared to 32% overall. This finding suggests that repeated interaction—even at low levels of depth—fostered trust. Again, it is important to note that these two key factors that influenced trust—proximity and prior professional relationships—were not especially amenable to policy influence, at least in the short term.

Discussion

To return to the original question that framed the article, what is the role of policy in teachers' social networks? This analysis suggests that policy can in fact play a role in influencing some dimensions of teachers' social networks, including its structure, the access to expertise that they afford, and the depth of interaction that occurs among individuals in the network. These dimensions of social networks are potentially important for curriculum implementation because they provide opportunities for social capital transactions, provide access to information and expertise to support learning, and foster the depth of interaction that may be necessary for teachers to grapple with new approaches in ways that help them to question their assumptions and reconfigure their instructional practice over time (Adler & Kwon, 2002; Burkhardt & Brass, 1990; Frank et al., 2004; Gibbons, 2004; Penuel et al., in press; Reagans & McEvily, 2003; Uzzi, 1997; Uzzi & Lancaster, 2003). However, this analysis also suggests that the design of the policy initiative matters. Creating more opportunities for teachers to meet may have limited impact if multiple priorities compete for teachers' time and attention (see Camburn, Kimball, & Lawenhaupt, 2008, on this point). The design of coaching—especially, selection criteria, work roles, and the focus of professional development—not only influences teachers' access to expertise; it also has implications for the degree to which teachers interact with depth and substance.

This study builds on prior research that provides evidence that school leaders and coaches mediate district policy (Coburn, 2001, 2005; Goldstein, 2004; Spillane et al., 2002). In this study, we show that school leaders configure

coaching resources in ways that shape the frequency and closeness with which teachers interact, as well as depth of interaction more broadly. School leaders also convey expectations for curriculum implementation that are influential for how teachers talk about the curriculum, both when they are interacting directly with the leadership and when they are interacting with one another when school leaders are not present. The messages conveyed by school leaders are not always congruent with the design of the curriculum or the district aims and may influence how teachers implement the curriculum in their classrooms. In short, school leaders may alternately interrupt or intensify district efforts to support the development of teachers' professional communities at the school site (Camburn et al., 2008).

This analysis has several implications for district policy. First and foremost, the study has implications for the design of coaching initiatives. Coaching is rapidly becoming the strategy du jour to support curriculum implementation in school districts. Yet this study provides preliminary evidence that the creation of the coach role alone does not increase teachers' access to expertise or the quality and rigor of their conversations with others. Rather, careful attention to professional development for coaches is important as well. It is important to foster greater expertise in coaches because it is a key strategy for bringing expertise into teachers' social networks, where they make everyday decisions about curriculum implementation. But it is also important because coaches draw on their experiences in professional development to structure their interactions with teachers. By developing robust routines of interaction to foster conversations about mathematics instruction and by using coaches as bridges to carry these routines into teachers' local networks, district leaders may create conditions in teachers' networks for deeper, more substantive, more classroom-focused conversations. Attention to these routines of interaction is especially important given the evidence presented here that the presence of carefully constructed routines foster depth of interaction, regardless of the expertise of the coach. Thus, this strategy may be especially useful in communities like Region Z, where there are not enough teachers with strong mathematical backgrounds and with experience in providing professional development to adequately staff school-based coaching initiatives.

This study also suggests greater attention to school leaders in district plans for curriculum implementation. In districts like those in the study where school principals have direct supervisory authority over coaches, the principals may choose to use coaches in ways that pull them away from direct interaction with teachers or that configure their time such that they rarely work with teachers in a sustained way. Furthermore, school leaders and coaches alike shape the degree to which teachers' talk focuses on district aims. School leaders in Region Z had much more haphazard and occasional ties to the mathematics reform activity in the district than did school leaders in Greene, who attended regular professional development for leadership teams that brought coaches and school leaders together to learn about mathematics and to learn to work together to lead the mathematics reform at their school sites. And it was school leaders in Region Z who were more likely to configure coaches' time in ways that worked against sustained content-focused interaction with teachers. Given the critical role of school leaders in determining how resources such as coaching and on-site professional development are used and given the degree to which they influenced the level of congruence at the school site, this study suggests the importance of bringing school leaders squarely into plans for curriculum implementation.

This study also makes several contributions to research on social capital and social networks. First, this study provides insight into the role of social policy in the nature and configuration of social networks. Social network and social capital researchers have historically paid little attention to the role of formal bureaucratic mechanisms (such as policy) in influencing informal social relations (Adler & Kwon, 2002). Social networks are an emergent phenomenon. They form as individuals opt into relationships with one another (Wellman & Berkowitz, 1988; Wenger, 1998). And, indeed, in this study, they formed as teachers sought out others inside and outside the school with whom to talk about mathematics instruction. However, this study provides evidence that social policy can indirectly influence this emergent process to the degree that it

shapes work roles and work flow, which in turn influence patterns of interaction. District policy created the role of the mathematics coach, and remarkably, even in Region Z, where the coaches lacked expertise, teachers almost uniformly reached out to the person in that role to discuss mathematics. At the same time, policy decisions about allocating coaches' time and effort influenced the degree to which teachers engaged with them with frequency and closeness.

However, this study begins to lay out some limits to the influence of social policy. Teachers reach out to others to form social networks for a range of reasons quite apart from any efforts to encourage their interaction (on this point, see Supovitz, 2008). In this study, teachers sought out others because they were close by. History matters as well, because teachers were more inclined to not only reach out to others with whom they had prior relationships but also trust them. This finding suggests that whereas policy can influence social networks by shaping patterns of interaction to some degree, it does not shape them entirely. Furthermore, policy initiatives cannot ensure that teachers will trust or feel close to those with whom they interact.

Second, this study advances research on teachers' social networks with its attention to the content of interaction. Researchers who use traditional social network analysis often draw broad inferences about what happens when individuals interact with members of their social networks, but they almost never measure it directly (Reagans & McEvily, 2003). Here, we offer a way to conceptualize and measure what teachers are doing when they interact with others in their social networks. Social capital theory highlights the importance of shared norms to achieve social capital benefits (Adler & Kwon, 2002). We show that attention to the content of those norms is important because teachers may indeed be having conversations that depart substantially from what the district or reform effort envisions, potentially leading teachers to modify their approach in ways that work against implementation. Furthermore, we provide evidence that all interaction is not the same; it varies greatly in its degree of depth, from swapping materials and activities to having substantive conversations about mathematical content or the nature of student learning. This suggests that not all social networks—even those with similar structure or similar expertise—have the same potential to foster teacher learning and instructional change.

Third, this study contributes to studies of social networks in education and beyond by providing evidence that more than just information flows along social networks. Prior studies of social networks have focused on the diffusion of information (Burt, 1992; Granovetter, 1982; Uzzi, 1997; Uzzi & Lancaster, 2003) or innovations (Burkhardt & Brass, 1990; Frank et al., 2004; Valente, 1995). Here, we show that routines of interaction flow through social networks as well. In this case, routines of interaction crafted by the district not only flowed into schools via the coach; once in the school, they moved from teacher to teacher as well. This phenomenon is important to recognize because routines of interaction have the potential to either interrupt or reinforce modal patterns of teacher interaction. And it suggests a different mechanism at work than that typically posited by social capital studies. Rather than generate social capital by being a conduit for resources (such as information and materials), networks can generate social capital by creating conditions that are more or less conducive for learning.

Fourth, this study raises methodological questions about existing studies of professional communities in schools. The majority of studies of teachers' professional communities use schools as the unit of analysis, using aggregate measures to assess the strength of a community schoolwide (see, e.g., Elmore et al., 1996; Lee & Smith, 1996; Louis et al., 1996; Louis & Marks, 1998; Newmann et al., 1996; Newmann et al., 2000; Rosenholtz, 1991). However, this study provides evidence that there is variability within schools on crucial dimensions—notably, trust, tie strength, and depth. Measuring community at the school level likely washes out this variation, creating a much less precise assessment of the nature of teachers' professional community. Other studies use the grade-level group or department to measure professional community (Achinstein, 2002; Little, 2003; Siskin, 1994), yet our study shows that teachers' social networks almost always stretch beyond grade-level groups to include others inside and outside the school. There was only one teacher in the study whose social network

for mathematics was confined to her grade-level peers. This finding suggests that rather than make assumptions, the locus of teachers' social networks is an important empirical question for investigation. In this regard, social network analysis presents a powerful analytic tool that allows the researcher to gain a much more precise understanding of the structure and content of teachers' professional relations,[16] something that is required if we are truly to understand the determinants of social networks on the one hand and the relationship between professional community and changes in teacher practice and student achievement on the other.

Finally, this study suggests several directions for future research. Our study identifies four dimensions of social networks that prior research suggests are consequential for the development of social capital. The purpose of this analysis has been to investigate the relationship between district policy and each of these four dimensions. However, future research is needed to develop a greater understanding of how these four dimensions interact to produce social capital. Close in, fine-grained studies that investigate the nature of the interrelationships between these dimensions will go a long way toward uncovering how features of a social network contribute to the social capital the network affords. Second, future studies should investigate the relationship between content of interaction—especially, depth—and such valued outcomes as implementation and student achievement.[17] Although there are theoretical reasons why depth and congruence are important to reform implementation, few studies in either the teacher professional community literature or the social capital literature have directly studied the relationship between what teachers talk about in their social networks and what changes they make in classroom practice. Early work on the relationship between the nature of teacher talk and teacher learning is instructive (Clark, 2001; Horn, 2005; Little, 2003). Future studies should take this work further to study the impact of the content of interaction on classroom practice and student learning.

Finally, our exploratory study has contributed to the literature by uncovering key features of district and school policy that appear to be related to changes in teachers' social networks. Future studies are needed to test the relationships proposed here in a larger sample, extending beyond high-poverty urban schools and districts, with a methodology that permits causal inferences to be drawn. As more and more schools and districts initiate reform efforts intended to promote teacher professional community, it becomes increasingly important to understand the consequences of these actions. Now that research documenting the positive effects of teacher professional communities has matured (Smylie & Hart, 1999), it is important for researchers to turn their analytic eye on the ways in which leadership and policy can support or constrain the development of productive social interaction among teachers that enables them to make positive instructional change.

Appendix A
Demographic Characteristics of the Students From the Case Study Schools

School	Number of students	Race/ethnicity (%)	Free/reduced-price lunch (%)	English-language learner (%)
Region Z				
School A	411	48: African American 45: Hispanic 5: White 1: Native American 1: Asian	88	9

(continued)

Appendix A (continued)

School	Number of students	Race/ethnicity (%)	Free/reduced-price lunch (%)	English-language learner (%)
School B	523	64: African American 33: Hispanic 1: Native American 1: White 1: Asian	86	10
School C	410	73: African American 23: Hispanic 1: White 1: Native American 1: Asian 1: Unspecified	93	9
School D	435	52: African American 47: Hispanic 1: White 1: Asian	83	11
District average	510	43: African American 41: Hispanic 11: White <1: Native American 4: Asian	85	12
Greene				
School E	883	9: African American 80: Hispanic 9: White	85	45
School F	914	7: African American 85: Hispanic 1: Native American 1: Other	93	57
School G	644	5: African American 89: Hispanic 5: White 1: Native American	99	52
School H	1,114	9: African American 70: Hispanic 19: White 1: Asian 1: Native American	73	45
District average	936	4: African American 83: Hispanic 11: White 1: Native American <1: Asian	86	50

Appendix B
Demographic Characteristics of Focal Teachers

Teacher	Grade	Gender	Years of experience	Race/ethnicity	Attitude about curriculum[a]
Region Z					
School A	—	—	—	—	3.65
EN	K	Female	6–10	White	4.00
BE	1st	Female	6–10	White	1.67
BT	2nd	Female	6–10	White	3.00
BH	3rd	Female	5	White	2.67
PQ	4th	Female	11+	White	1.33
QJ	5th	Female	4	White	2.00
School B	—	—	—	—	2.84
DS	K	Female	11+	African American	3.00
NH	2nd	Female	2	White	4.33
OG	2nd	Female	6–10	No info	No info
UF	3rd	Male	11+	White	4.00
HQ	4th	Female	11+	Native American	2.67
NC	5th	Female	4	White	3.00
School C	—	—	—	—	2.86
TP	K	Female	6–10	White	2.00
EB	1st	Female	4	White	2.33
TT	2nd	Female	11+	African American	4.33
TF	3rd	Female	6–10	Middle Eastern	1.33
UW	4th	Female	6–10	Hispanic	3.00
MD	5th	Male	4	African American	4.33
School D	—	—	—	—	3.31
MF	K	Female	11+	African American	3.00
NE	K	Female	6–10	White	2.67
KD	1st	Female	6–10	White	2.67
KT	2nd	Female	11+	White	4.00
EN	3rd	Female	11+	White	2.67
UD	5th	Male	5	African American	3.00
Greene					
School E	—	—	—	—	3.16
QS	K	Female	11+	White	4.00
SN	1st	Female	6–10	Hispanic	3.33
KE	2nd	Female	5	White	3.00
BX	3rd	Female	2	White	2.67
SD	4th	Female	1	Hispanic	3.00
LX	5th	Female	3	White	1.33
School F	—	—	—	—	2.63
CD	K	Female	1	White	2.50
XN	1st	Female	2	White	3.33
NQ	1st	Female	6–10	Hispanic	4.33
LH	2nd	Female	4	White	3.67
KN	4th	Female	11+	White	2.33
DT	5th	Male	5	White	3.33
School G	—	—	—	—	3.23
FT	K	Female	11+	White	4.33
WH	K	Female	6–10	Hispanic	3.00
LI	2nd	Female	3	White	3.33

(continued)

Appendix B (continued)

Teacher	Grade	Gender	Years of experience	Race/ethnicity	Attitude about curriculum[a]
LH	3rd	Female	2	Hispanic	4.00
TS	4th	Female	4	White	2.33
NN	5th	Female	3	African American	3.33
School H	—	—	—	—	3.40
UN	1st	Female	6–10	White	3.67
SH	2nd	Female	6–10	White	1.33
KH	3rd	Female	6–10	White	2.67
DN	5th	Female	6–10	Hispanic	4
TI	2nd	Female	No info	No info	No info
QK	4th	Female	No info	No info	No info

a. Scores represent the mean response to three questions about the curriculum (1 = *strongly disagree*, 5 = *strongly agree*).

Appendix C
Definitions of Key Dimensions of Social Networks

Dimension	Definition
Access to expertise	
Low	A network is considered to afford access to low expertise if there is no one who has either moderate or high expertise. There must be information about at least two thirds of nominated teachers in a network to be considered low expertise.
Medium	A network is considered to afford access to moderate expertise if there are one or more people in the network with moderate expertise but no one with high expertise. *Moderate expertise* is defined as two or three intensive professional development experiences or mathematics major as an undergraduate or specialization in mathematics in graduate school accompanied by at least some opportunity to learn about pedagogical approaches related to the curricula.
High	A network is considered to afford access to high expertise if there are one or more people in the network with high expertise. *High expertise* is defined as four or more intensive professional development experiences or a math major in undergraduate or specialization in mathematics education in graduate work accompanied by two or more intensive professional development experiences.
Congruence: *Everyday Mathematics*	
Congruent	Talk related to one or more of the following: the importance of developing students' conceptual understanding and computational fluency, importance of attention to students' strategies for solving problems, benefits gained by the use of multiple representations, the logic of spiral curriculum, order of presentation, and coverage of materials
Incongruent	Talk related to one or more of the following: focus on explicit teaching of algorithms, explicit test preparation, skipping or modifying lessons, focusing only on secure goals
Congruence: *Investigations*	
Congruent	Talk related to one or more of the following: the importance of developing students' conceptual understanding and computational fluency, importance of attention to students' strategies for solving problems, benefits of using multiple

(continued)

Appendix C (continued)

Dimension	Definition
	representations, modifying lessons midstream in response to student learning needs, supplementing the curricula in ways that are congruent with the *Investigations* approach
Incongruent	Talk related to one or more of the following: focus on explicit teaching of algorithms, explicit test preparation, modifying lessons at the outset, striving for efficiency in student strategies
Depth	
Low	Talk related to one or more of the following: how to use materials; how to coordinate the text, standards, assessments, and pacing guides; how to organize the classroom; sharing materials or activities; general discussions of how a lesson went or whether students were getting it
Medium	Talk related to one or more of the following: discussions of how lessons went, including a discussion of why; detailed planning for lessons, including a discussion of why; specific and detailed discussion of whether students were learning (but not how students learn); discussion of instructional strategies in the context of observations; doing mathematics problems together with discussion
High	Talk related to one or more of the following: pedagogical principles underlying instructional approaches; how students learn, or the nature of students' mathematical thinking; mathematical principles or concepts

Notes

[1]Some theorists equate trust with social capital (Adler & Kwon, 2002). We take the stance that the two are not synonymous; rather, trust is a precondition or a source for the development of social capital. In other words, trust between actors in a social network enables the type of interaction that allows access to valued resources.

[2]Some social capital research does purport to address the content of social networks. But this work conceptualizes content as the functional area of communication, such as work-related advice networks versus friendship networks (e.g., Gibbons, 2004; Reagans & McEvily, 2003). These broad categories of content fail to capture the wide variation in what is talked about in social networks, which is the focus of our investigation of the content of interaction.

[3]Names of districts, schools, and individuals are all pseudonyms.

[4]We provided district leaders with a rubric with our definitions of *high human capital*, *low human capital*, *high social capital*, and *low social capital*. District leaders used these rubrics to nominate schools for the study. The rubric described what schools with high versus low social capital might look like along four dimensions: trust, collaboration, common vision, and interaction. It also described what schools with high versus low human capital might look like along three dimensions: knowledge, pedagogy, and understanding of mathematics learning. The complete copy of the rubric is available upon request from the first author.

[5]To cross-check the attitudes toward the curriculum with the principals' recommendations, we used survey questions (via a Likert-type scale) that asked teachers to agree or disagree with the following statements: "[The curriculum] does not emphasize the things that are important for students to learn in mathematics" (reverse-coded); "[The curriculum] is not a complete curriculum and must be supplemented" (reverse-coded); and "[The curriculum] is not effective with students who speak English as a second language" (reverse-coded).

[6]Consistent with the other schools in the district, all case study schools in Region Z had a single full-time mathematics coach. Consistent with other schools in Greene, three case study schools had two half-time coaches; a fourth had three half-time coaches.

[7]Research by Spillane (2005) provides evidence that teachers' social networks can vary substantially by subject matter. For this reason, we asked about teachers' ties in mathematics rather than about whom they interacted with more generally.

[8]Copies of the interview protocol—and, indeed, all instruments used in this study—are available by request to the first author.

[9]By contrast, sociocentric approaches to network analysis provide lists of organization members and ask individuals to indicate the degree to which they interact with each person on the list. This approach

presumes that the boundaries of individuals' social networks are circumscribed by organizational boundaries (Carrasco, Hogan, Wellman, & Miller, 2006; Reagans & McEvily, 2003).

[10]It is important to recognize, however, that Bryk and Schneider's work (2002) is interested in principal–teacher trust, teacher–teacher trust, teacher–student trust, and school staff–parent trust. Here, we are mainly concerned with trust between the teacher and those that they nominated in their social networks, which included colleagues, school leadership, coaches, and a range of individuals outside the school. Because teachers did not nominate parents or students as people to whom they reached out to discuss mathematics, parents and students do not play a role in our analysis of trust.

[11]We recognize that participation in professional learning opportunities related to reform mathematics is not a direct measure of teacher expertise. Instead, it measures opportunities to develop expertise. Measuring teacher subject matter expertise has been notoriously difficult (see Hill, Rowan, & Ball, 2005, for a review). It is even more challenging in this instance because we must measure the expertise of each person in a focal teacher's social network to characterize the access to expertise afforded by the network as a whole. Although we included measures of pedagogical content knowledge developed by Deborah Ball and Heather Hill in our teacher survey—a more direct measure of expertise—we were not able to access individual-level answers for nonfocal teachers who were members of focal teachers' social networks, owing to human participant protections. (We were able to get individual-level data from the survey for focal teachers.) Thus, we rely instead on the proxy measure of participation in learning opportunities, such as professional development and course work.

[12]The researchers in one school in Region Z failed to ask the battery of questions necessary to ascertain the degree of expertise in focal teachers' networks. Thus, we cannot include five of the six teachers in that school in our analysis of access to expertise. Fortunately, we were able to ascertain the expertise of the coach and school leaders.

[13]As part of our interview protocol, we asked teachers, coaches, and school leaders about norms of interaction related to mathematics before the start of the initiative. We then identified specific interactions mentioned in these responses and coded them according to depth. We were not able to triangulate interview data with observations on these historical data as we did with data on interactions that took place during the study year. Furthermore, historical reports are always subject to the limits of memory. Thus, although we are heartened because the historical findings are consistent with the extant literature that describes modal teaching interaction in schools across the country (Little, 1990; Lortie, 1975; McLaughlin & Talbert, 2001), this finding should be treated with caution.

[14]The remaining 50% of interaction in both districts was more consistent with modal teacher interaction as documented by previous studies. There was a high frequency of storytelling, sharing materials and activities, and quick advice. Discussions of pacing ("Where are you in the curriculum?" "Where do we need to be by the end of next month?") and lesson planning were also common.

[15]One possible explanation for the discrepancy between our finding and those of other studies involves the difference in methodology that we used to ascertain trust. Prior studies have tended to measure teachers' perceptions of trust at the school level, and they have done this by asking teachers to report their perceptions of trust levels in the school in general. In contrast, our unit of analysis was focal teachers' social networks, and we assessed the degree to which focal teachers trusted each individual that they nominated in their networks, as opposed to asking them about their perceptions of trust in general. Our approach is quite fine-grained, and it may be surfacing variation among focal teachers in a school and in teachers' responses to others in their own networks, which cannot be assessed at the larger unit of analysis or more general way of asking the question. In response to feedback from an early reader, we investigated whether teachers' degree of trust for the principal influenced their overall levels of trust in their network. In their rich case studies of the dynamics of relational trust in schools, Bryk and Schneider (2002) show that the same qualities in principals that led teachers to trust them or not also created conditions in schools that enabled teachers to trust one another. However, in our study, there was great variability in whether teachers trusted the principal in a given school, and we did not find a relationship between whether a given teacher trusted the principal and the overall levels of trust they had in their network.

[16]See also, Bidwell and Yasumoto (1999) and Frank and Zhao (2004) for examples of studies that use social network analysis to investigate teachers' professional relations.

[17]Although we refer to curriculum implementation in this case as a valued outcome, it is important to acknowledge that teachers may have valid reasons for not implementing some policies, especially given that not all district policies related to teaching and learning are equally educationally sound.

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