AMERICAN SOCIOLOGICAL ASSOCIATION

Sociology of Education
2017, Vol. 90(2) 149–171

DOI: 10.1177/0038040717696151
journals.sagepub.com/home/soe
SAGE

The Elephant in the Schoolhouse: The Role of Propinquity in School Staff Interactions about Teaching

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Abstract

Although the physical arrangement of workspaces can both constrain and enable interactions among organizational members, sociological research in education has not extensively examined the role of physical proximity in determining work-related social ties among school staff. Using social network analysis, this article explores the relationship between physical proximity and instructional advice seeking among school staff in all 14 elementary schools in one U.S. school district over four years. Results show that school staff whose workspaces are located closer to one another, and whose paths likely cross more frequently in their day-to-day work within the school building, are more likely to talk with one another about their work. Findings argue for more careful consideration when assigning school staff to workspaces, as the physical proximity of school staff appears to play a significant role in who talks to whom about instruction.

Keywords

teachers, networks, proximity, space, advice

For much of the twentieth century, the image of U.S. teachers that emerged from sociological research—as captured in classics such as Waller's (1932) *Sociology of Teaching* and Lortie's (1975) *Schoolteacher*—was that of isolates, practicing alone in their classrooms. Teaching operated as something of a cottage industry, with teachers working alone behind closed classroom doors, operating independently of peers, and exercising considerable autonomy over their practice (Bidwell 1965; Lortie 1969, 1975). Over the past few decades, however, sociologists and education researchers have offered another portrayal of the school workplace, one where teachers work together to plan lessons, solve instructional problems, and improve their teaching (Bryk, Camburn, and Louis 1999; Bryk and Schneider 2002; Goddard, Goddard, and Tschannen-Moran 2007; Lee and Smith 1996; Little 2003; Rosenholtz 1985; Smylie 1995). Both portrayals are likely accurate depictions of workplaces in school systems across the United States today.

When teachers work together on matters of instruction, it often, although not always, contributes to improvement in valued school outcomes, such as student performance (Bryk and Schneider 2002; Frank, Zhao, and Borman 2004; Pil and Leana 2009). Teachers' interactions provide them with access to resources, such as information, support, materials, and encouragement,

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which can foster innovation and the development of new knowledge about teaching (Coburn 2001; K. Davis 2003; Goddard et al. 2007; Little 2003; Louis, Marks, and Kruse 1996; Penuel et al. 2009; Smylie 1995). Sociologists describe these social resources using the construct of social capital, which denotes real or potential resources for action attained through relations with others (Bourdieu 1986; Coleman 1988; Lin 1982, 2001). Indeed, many studies document substantial returns to social capital in schools and school systems (Bryk and Schneider 2002; Coburn 2001; Daly and Finnigan 2010; Daly et al. 2010; Frank et al. 2004, 2011; Louis et al. 1996; Moolenaar et al. 2014). Still, forging workplaces where teachers work together on instruction and build social capital is difficult, and at times it results in "contrived collegiality," which does little to improve teachers' classroom practice (Datnow 2011; Hallett 2010; Hargreaves 1994; Little 1990; Spillane, Parise, and Sherer 2011).

Along with the returns from teachers' interactions with peers, research also documents the conditions, including norms and formal organizational arrangements, that facilitate staff interactions about instruction (Bryk et al. 1999; Bryk and Schneider 2002; Coburn 2001; Lee and Smith 1996; Little 1982; Mawhinney, Haas, and Wood 2005; Rosenholtz 1985; Supovitz 2006; Tschannen-Moran 2001). Understanding the conditions that facilitate these interactions is important, because social interactions are key building blocks of social capital, and these are neither "a natural" nor "a social given" (Bourdieu 1986:249). Research shows that the normative structure of the school workplace is critical to fostering staff interactions about instruction: in schools with shared norms that support openness to innovation, trust, and collective responsibility for student learning, teachers are more likely to interact about instruction in ways that enable instructional improvement (Bryk and Schneider 2002; Little 2003; Louis et al. 1996; Rosenholtz 1985; Scribner, Hager, and Warne 2002; Smylie 1988; Tschannen-Moran 2001). Moreover, formal organizational structures, such as organizational routines and leadership positions, enable staff interactions about instruction: for example, prior work finds that formal teacher leadership positions (e.g., instructional coaches) and structured work time for instructional teams enable teachers to learn from one another about instruction (Coburn and Russell 2008; Ronfeldt et al. 2015; Spillane, Hopkins, and Sweet 2015, 2016).

Prior work largely focuses on the ways norms and formal organizational arrangements influence workplace interactions among school staff. This research suggests, but leaves mostly unexamined, something fundamental to workplace interactions: the role of schools' *physical* infrastructure—specifically, the propinquity of staff within school buildings—in enabling or constraining these interactions. (We use the term *propinquity* to refer to physical proximity in the workplace, and we use the terms *propinquity* and *proximity* interchangeably.) The inattention to how physical space enables or constrains interactions is surprising for at least two reasons. First, Giddens (1984:363) reminds us that space is a critical component of human institutions: "Spatial configurations of social life are just as much a matter of basic importance to social theory as are the dimensions of temporality." Second, a modest literature on organizations other than schools documents how spatial arrangements both constrain and enable interactions among organizational members in much the same way that social norms, formal organizational structures, and other aspects of the social situation do. Yet scholars of the school workplace have mostly ignored the role of propinquity in determining interactions among school staff, even though schools differ in some respects from other organizations. Specifically, teachers have traditionally worked mostly as isolates, and efforts to encourage teachers to work together are relatively recent. Furthermore, schools tend to have flat organizational structures. Most staff are accountable directly to the school principal, and grade levels (at the elementary level) or departments (at the middle or high school levels) are the dominant organizational arrangements. Thus, while we have some reasons to expect that propinquity may operate in similar ways in schools as in other organizations, there are also reasons to expect it might operate differently. Accordingly, our main research question is, how—if at all—does propinquity influence interactions among school staff about instruction?

We take up our research question by bringing the literature on propinquity in organizations into dialogue with the literature on teacher interactions in the schoolhouse. Our study documents how propinquity—the elephant in the schoolhouse that prior work on school staff interactions has largely ignored—influences interactions among elementary school staff. Using a mixed-methods research design, we first show that propinquity matters to

interactions among school staff and then, using qualitative and quantitative data, we theorize *how* it matters to these interactions.

We contribute to the literature on teachers' workplace interactions in several ways. First, we show that propinquity influences school staff interactions about teaching. Second, we demonstrate that propinquity influences staff interactions when it is defined either as the walking distance between workspaces or by the overlap of individuals' frequently traveled areas within school buildings. Third, we show that grade-level assignments moderate propinquity's effects on interactions, such that propinquity has a stronger impact on interactions that take place between staff who teach the same grade level than on interactions between staff who teach different grade levels. Fourth, we draw on interview data to identify two mechanisms through which propinquity enables school staff interactions about instruction: first, propinquity decreases the time and effort required to interact with colleagues; second, propinquity increases the likelihood of chance encounters between staff.

FRAMING THE RESEARCH: EMPIRICAL AND THEORETICAL ANCHORS

Rivera, Soderstrom, and Uzzi (2010:92) synthesize the sociological literature on the "existence, creation, persistence, and dissolution of social relationships among social actors" into three categories, each reflecting a unique sociological tradition: (1) "assortative perspectives," which center on compatibility between actors' attributes; (2) "relational perspectives," which focus on how actors are positioned in social networks; and (3) "proximity perspectives," which attend to how social interactions are organized in time and space. The proximity perspective is most relevant to framing our investigation of the relationship between propinquity and work-related interactions in schools. We begin, however, with a brief overview of the literature on the assortative and relational perspectives, as our analysis controls for some of these influences. Throughout this article, we use the social network term *ties* interchangeably with the more general term *interactions* to refer to work-related social interactions among school staff.

Assortative, Relational, and Organizational Predictors of Social Interactions

Assortative factors explore how similarity in terms of characteristics such as age, race, gender, education, and values affects social interaction (Ibarra 1992; Lazarsfeld and Merton 1954; McPherson, Smith-Lovin, and Cook 2001; Mollica, Gray, and Trevino 2003; Monge and Contractor 2003). Often called "homophily," various studies offer empirical support for the observation that "birds of a feather flock together," particularly in regard to race/ethnicity (Mollica et al. 2003; Shrum, Cheek, and Hunter 1988), education (e.g., Marsden 1987), gender (Ibarra 1992; Leenders 1996), and age (Feld 1982).

Some recent research on schools suggests that homophily in terms of race and gender has a small but statistically significant relationship with work-related advice and information interactions among school staff (Spillane et al. 2010; Spillane, Hopkins, and Sweet, 2015). In contrast to these relatively small associations, however, homophily with respect to position in elementary schools' formal organization—that is, teaching the same grade—has a much larger relationship with work-related interactions (Moolenaar et al. 2014; Spillane et al. 2010, 2015; Spillane, Kim, and Frank 2012). Because our sample of elementary school staff is almost entirely homogenous in terms of race and gender (see Research Approach), we are unable to examine the impacts of race and gender homophily on interactions here. Instead, we control for the most important assortative factor found in prior research on work-related ties in schools—teaching the same grade level—in an effort to isolate the relationship between propinquity and work-related interactions among school staff. In other analyses, we interact our propinquity measures with a same-grade indicator to explore the relationship between these predictors.

Based on the importance of triadic ties (Simmel 1908), work in the relational tradition suggests that how actors are positioned in a social network at a given time has consequences for their future interactions (Stuart and Sorenson 2007). Among other things, this work suggests that individuals connected through an intermediary are likely to establish an interaction (J. Davis, Holland, and Leinhardt 1971; Feld 1997; Granovetter 1973), actors who are more central in a social

network are quicker to establish ties to others (Barabási and Albert 1999; Newman 2002; Price 1976; Uzzi 2008), and central actors are more likely to have ties to other central actors than to actors that are more peripheral in the network (Perrucci and Pilisuk 1970). Ties also tend to be reciprocated over time (Doreian et al. 1996; Hallinan 1978; Mollica et al. 2003; Runger and Wasserman 1980), and triadic closure often emerges in a network (Hammer 1980; Kossinets and Watts 2006). Overall network size is also a predictor of ties, with ties generally more likely to form in smaller networks (Wasserman and Faust 1994). To control for such relational influences on work-related social ties, we use a class of social network models that implicitly control for such influences, and we control for network size in our models (see Research Approach).

Recent work on social capital (Small 2009) and on interactions among school staff (Moolenaar et al. 2014; Spillane et al. 2010, 2015) suggests another category of influences on social interactions: formal organizational arrangements, including formal positions (e.g., holding a leadership role, such as administrator or teacher leader) and teaching assignments (e.g., teaching a single grade or teaching multiple grades). These formal organizational arrangements are not only statistically significant predictors of social ties, but they have larger effects on the likelihood of ties than do individual attributes, such as race and gender (Spillane et al. 2010, 2015). Our analyses control for two important aspects of the formal organization: whether a staff member was assigned a leadership role, such as principal, coach, or grade-level leader, and whether a staff member taught students in multiple grades.

Propinquity as a Predictor of Social Interactions

Physical proximity, or propinquity, also influences the likelihood that people interact. This is true across countries (Leskovec and Horvitz 2008), within neighborhoods (Festinger, Schachter, and Back 1950; Sudman 1988), and—most relevant for our work—within organizations, even those contained in a single building (Marmaros and Sacerdote 2006). Social ties are also associated with physical proximity within workplaces. The distance between workspaces predicts workers' likelihood of collaboration and friendship; this finding has been replicated in various settings, including engineering offices (Allen 1977; Allen and Fustfeld 1975), scientific offices (Kabo et al. 2015), architectural firms (Backhouse and Drew 1992), state legislatures (Caldeira and Patterson 1987), and police academies (Conti and Doreian 2010).

Most of these studies use either walking distance or "as-the-crow-flies" distance between workspaces to measure propinquity. Some work, however, explores the role that "functional distance" plays in the likelihood of workplace interactions. Functional distance is a means of operationalizing propinquity that acknowledges that the physical spaces in which interactions take place shape those interactions by bringing people into more or less frequent contact with one another (Festinger et al. 1950). Building designs, for example, dictate workers' required paths in a building and therefore determine to a large degree the likelihood that individuals come into contact and interact (Festinger et al. 1950; Kabo et al. 2014). Functional distance is related to physical distance, but it incorporates building designs, and their effects on social interaction, to capture "how human behavior interacts with spatial layout to produce proximity" (Kabo et al. 2014:1471).

In the workplace, research finds that patterns of movement are strongly associated with work-related social interactions. For example, density of movement within particular areas (particularly, staircases and corridors) is associated with increased frequency of interaction (Penn, Desyllas, and Vaughan 1999). Similarly, a study that examined an academic setting found that faculty whose offices were located along central corridors had greater rates of coauthorship than did colleagues whose offices were more peripheral (Wineman, Kabo, and Davis 2009). Other work found that the central aisle of a large collaborative workspace is often the densest area of interaction (Hillier and Grajewski 1990).

Functional distance is a more powerful predictor of work-related ties than is mere physical distance. One study, for example, found that although the effects of physical distance on collaborations between scientists varied by overall building topology, functional distance exerted more consistent effects (Kabo et al. 2015). Other work found that more complex measures of functional distance outperformed simple measures of distance as predictors of work-related social ties (Sailer and McCulloh 2012). In this study, to capture this more nuanced view of the role of propinquity

in workplace interactions among school staff, we follow prior work (Kabo et al. 2014, 2015) and operationalize functional distance as the overlap between the "functional zones" of two staff members (see Research Approach).

Of course, it is difficult to rule out endogenous processes as explanations for proximity effects. If individuals who collaborate seek out—or are assigned—office spaces close to one another, propinquity and social interaction could be associated, but instead of propinquity predicting ties, ties themselves may predict propinquity. As in all nonexperimental studies, the associations we uncover between propinquity and ties cannot necessarily be interpreted causally. Network researchers note as much, acknowledging that existing spatial configurations may both reproduce and produce particular patterns of social relations (Bafna 2003). However, studies that examine the associations between propinquity and workplace collaborations have found similar associations between proximity and interactions in diverse settings, including settings with relatively little turnover in office assignments, suggesting that such endogenous assignments of office spaces do not entirely explain the associations between propinquity and social interactions (Kabo et al. 2014, 2015). We conducted several analyses to attempt to rule out the possibility that propinquity and ties are endogenous.

Although we focus most of our analyses on examining the relationship between propinquity and work-related interactions among school staff, it is also important to understand *how* propinquity influences social interactions—in other words, what are the mechanisms by which propinquity influences interactions? Some scholars theorize that propinquity influences social ties because less effort is required to connect with individuals who are physically closer, compared to individuals who are more distant (Zipf 1949). Distance increases the "cost" of interaction, and the likelihood of an interaction decreases as this cost increases (Glaeser and Sacerdote 2000; Kabo et al. 2015; Marmaros and Sacerdote 2006). Other scholars theorize that physical proximity influences social ties because of exposure: the greater the propinquity between two people, the more likely they are to be exposed to one another, and the greater their likelihood of a social tie (Kabo et al. 2014). Exposure matters because unplanned, brief, face-to-face encounters enable social interactions (Festinger et al. 1950; Kabo et al. 2014; Kuper 1953; Small 2013). This is one reason why exploring propinquity not just in terms of walking or "as-the-crow-flies" distance, but also in terms of functional distance, is important: movement patterns can bring individuals into "incidental proximity" in highly trafficked areas, contributing to unplanned and unexpected interactions (Backhouse and Drew 1992). Our analyses therefore take both approaches to measuring propinquity.

RESEARCH APPROACH

Our analysis is based on a longitudinal mixed-methods study that examined school staff interactions about instruction in all 14 elementary schools in a mid-sized U.S. school district we call Auburn Park (AP). AP is a suburban district serving 5,900 elementary school students, mostly white (82 percent), with small populations of Latino/a (6 percent) and African American (5 percent) students, and a significant number of students (25 percent) qualifying for free or reduced school lunch. Nearly all AP elementary teachers are white (98 percent).

Data Sources

In the spring of 2010, 2011, 2012, and 2013, all elementary school teachers and administrators in AP's elementary schools were sent a survey that asked them about their day-to-day work, their perceptions of their schools, their backgrounds, their work-related interactions, and their room number. Survey response rates were 81 percent in 2010 ($n = 331$), 95 percent in 2011 ($n = 393$), 94 percent in 2012 ($n = 375$), and 94 percent in 2013 ($n = 384$). Response rates above 70 percent are essential for social network analysis (Wasserman and Faust 1994).

Social network data. The surveys included several items designed to elicit work-related social networks that were developed and validated in prior studies (Pitts and Spillane 2009; Pustejovsky and Spillane 2009). Specifically, the surveys asked staff about two distinct types of work-related social networks: close colleague networks and instructional advice and information networks. To elicit staff's close colleague networks, the surveys asked, "Who are your closest colleagues in your school?" and allowed respondents to list up to 12 individuals. To elicit staff's

Table 1. Descriptive Statistics, Auburn Park, 2010 to 2013.

Variable	2010	2011	2012	2013
Panel A: Networks				
Colleague networks				
Number of ties/staff member	3.69 (1.09)	3.95 (0.63)	3.64 (0.72)	3.43 (0.50)
Network density	0.17 (0.04)	0.15 (0.03)	0.15 (0.04)	0.14 (0.03)
Math networks				
Number of ties/staff member	1.47 (0.45)	1.65 (0.40)	1.60 (0.40)	1.62 (0.31)
Network density	0.07 (0.04)	0.06 (0.01)	0.07 (0.02)	0.07 (0.02)
Language arts networks				
Number of ties/staff member	2.32 (0.76)	2.32 (0.59)	2.08 (0.48)	1.98 (0.43)
Network density	0.11 (0.03)	0.09 (0.02)	0.09 (0.02)	0.08 (0.02)
Panel B: Covariates				
Individual (node) level				
Taught multiple grades	0.31 (0.46)	0.29 (0.45)	0.26 (0.44)	0.26 (0.44)
Leadership role	0.21 (0.41)	0.20 (0.40)	0.19 (0.39)	0.17 (0.37)
Years of experience	12 (9)	12 (9)	12 (9)	11 (9)
Nodes, *n*	312	374	349	360
Pair (dyad) level				
Same grade	0.42 (0.49)	0.39 (0.49)	0.38 (0.49)	0.37 (0.48)
Distance (walking distance)	225 (108)	221 (105)	221 (107)	222 (106)
Distance (zone overlap)	348 (123)	337 (112)	341 (116)	333 (103)
Dyads, *n*	7,336	9,898	8,790	9,172
Network level				
Network size	22 (7)	27 (5)	25 (6)	26 (5)
Networks, *n*	14	14	14	14

Note: Standard deviations in parentheses. Distance measures are in feet units. For purposes of this table, functional zones for zone overlap measures are defined as the paths between individual workspaces, the principal's office, and the school lunchroom.

instructional advice and information ties, the surveys asked, "During this school year, to whom have you turned to for advice and/or information about curriculum, teaching, and student learning?" Respondents could list up to 12 individuals as well as the specific content areas for which they sought advice or information from each person, including reading/English language arts (henceforth "language arts") and mathematics. There are similarities in close colleague and instructional advice networks, but these networks are distinct and we analyze them separately here. We do not consider ties between individuals in different schools for two reasons: first, we denoted the boundary of each network as the school because we are interested in within-school propinquity; second, across-school ties were generally quite rare.

In AP, close colleague networks were the most dense, with between three and four ties per staff member, on average, across the four years of our study (see Panel A in Table 1); language arts networks were significantly less dense, with an average of approximately two ties per staff member; and math networks were the least dense, with approximately 1.5 ties per staff member, on average. Across the four years, average network size in AP ranged between 22 and 27 staff members.

Physical proximity data. To determine the physical proximity between workspaces, we used architectural floor plans of all 14 AP elementary schools to locate the workspaces of all survey respondents who listed a room number on the survey. We also located the important shared spaces in each school building, including principals' offices, staff restrooms, building entrances and exits, playground accesses, and shared spaces, such as art rooms, gyms, lunchrooms, and libraries. To verify and complete this information, we conducted semistructured interviews with five AP principals in the spring of 2015, in which we

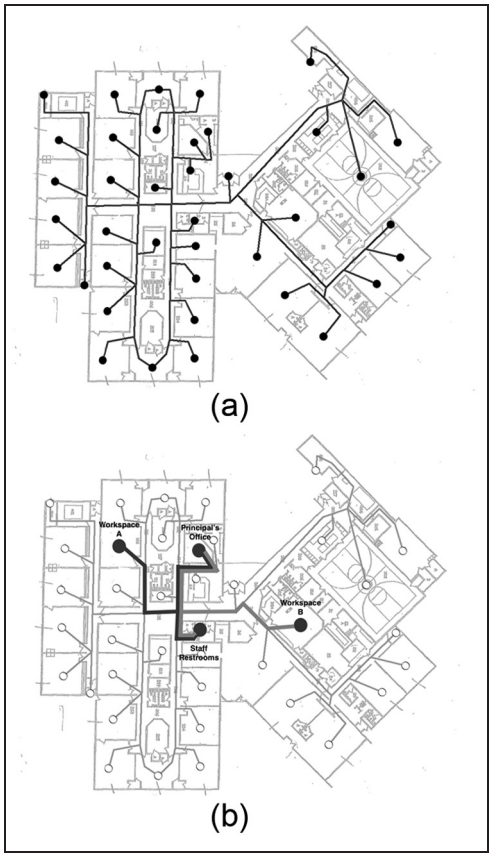

Figure 1. Illustrations of propinquity measures. Panel A: Walking distance. Panel B: Functional zone overlap.

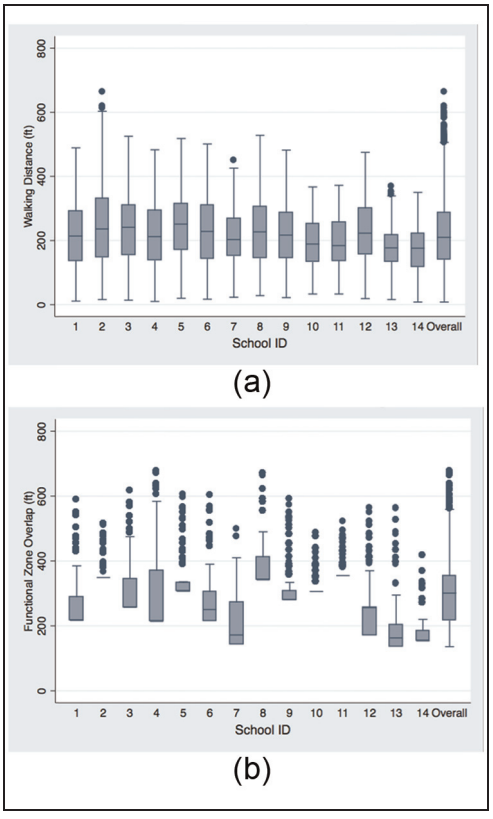

Figure 2. Distributions of propinquity measures in Auburn Park schools. Panel A: Walking distance. Panel B: Functional zone overlap.

shared maps of their school buildings with our workspace locations marked and asked them to correct these maps and point out omissions. These interviews generally verified our locations of workspaces in these buildings, and the remaining AP principals reviewed our maps via e-mail and corrected any remaining omissions or errors. Using these maps, we then used ArcGIS to create a "segment map" (Hillier and Iida 2005; Sailer and McCulloh 2012) of each school by marking the approximate center of each workspace and the within-building paths between them.[1] Panel A in Figure 1 shows an example of such a segment map for one AP school.

Using these segment maps, we created two distinct measures of propinquity, both of which build on prior work using "space syntax" methods (Bafna 2003; Hillier and Hanson 1984), the most advanced available approach for studying the relationship between propinquity and ties (Kabo et al. 2014). The first measure of propinquity is the walking distance between workspaces (in feet), which we calculated using ArcGIS. Panel A of Figure 2 shows box plots depicting the distributions of walking distances in each AP school as well as for the 14 schools overall. Across the district, the average walking distance between locations in school buildings was 220 feet, with a standard deviation of 102 feet. Several schools had some locations separated by 11 feet or less, and in one school, two locations were more than 660 feet apart.

Our second measure of propinquity is based on the concept of "functional zones" (Kabo et al. 2014, 2015). A functional zone is the area of a building likely to be frequently trafficked by an individual; it is defined as the path between a workspace and several other key locations in a building (Kabo et al. 2014, 2015). Because

functional zones measure "individual spheres of operation" in the workplace (Kabo et al. 2015:63), the degree of overlap between two individuals' functional zones measures the likelihood they will have chance encounters that may increase the likelihood of a tie (Kabo et al. 2015).[2]

We defined a staff member's functional zone as the path that connected that staff member's workspace (classroom or office) with two of the following locations: the principal's office, staff restrooms, photocopier location, student lunchroom, and nearest entrance/exit to the building. Panel B of Figure 1 shows a segment map for the same school as Panel A, but it illustrates the functional zones of two school staff members, marked A and B. The functional zone for staff member A (black line) is the path that connects this staff member's classroom to the principal's office and the staff restroom; the gray line marks the same zone for staff member B. The area where these two zones overlap (shown side by side in the figure) is the overlap of their functional zones, measured in feet for our analyses. Depending on the positioning of any two staff members' workspaces, as well as their locations relative to other important locations in the building, the overlap of their functional zones can vary a great deal.[3]

Because our results were qualitatively similar regardless of the specific definition of functional zones we used, we include two measures of functional zones: first, the path connecting an individual's workspace, the staff restroom, and the nearest entrance/exit to the school building; second, the path connecting the workspace, school lunchroom, and principal's office. We chose these two measures of zone overlap because they are the least correlated of any pair of our functional zone overlap measures (r = .19, n = 573). We examined functional zone overlap using each possible definition of functional zones to determine whether the specific definition of the zone influenced our results. Appendix A shows descriptive statistics for each measure of functional zones, and correlations between these measures are in Appendix B.

Functional zone overlap varied a great deal between schools, as seen in Panel B of Figure 2, which depicts the distributions of functional zone overlap, in feet, for each of the 14 AP elementary schools and for the 14 schools overall, defining functional zones as the paths between a staff member's workspace, the principal's office, and the school lunchroom. The distribution of zone overlaps within schools was generally right-skewed, and the school mean zone overlap ranged from 185 to 400 feet across the district. Zone overlap varied by school no matter how functional zones were defined. The 14 school buildings were roughly similar in size, so the variation in zone overlap was likely due to variation in the layouts of workspaces and other locations within those buildings.

Interview data. We conducted semistructured interviews during the 2011–2012 school year with a purposeful sample of 33 school staff in five AP schools, selected to maximize variation on dimensions important to interactions among school staff about instruction, with a particular focus on mathematics. We selected schools that served students from low-income families and schools that did not; we also chose schools that represented a range of organizational infrastructures, such as schools with and without math coaches, as prior work suggests this would be an important influence on staff interactions about mathematics (Spillane et al. 2012).

We sampled school staff who held different formal positions (e.g., principal, teacher leader, teacher) and who occupied different positions in their schools' mathematics advice and information networks (e.g., highly connected and weakly connected). We asked interviewees about whom they interacted with about mathematics, how, and why, and to describe the nature and content of those interactions; our semistructured interview protocol did not include specific questions about propinquity. Interviews lasted 40 to 50 minutes and were audio recorded, transcribed, and imported to NVivo for analysis.

Analytic Procedures

Social network analysis. Ties between individuals do not satisfy the assumption of independence of observations necessary for standard regression methods (Wasserman and Faust 1994), so we used social network methods to examine whether propinquity predicted ties between school staff. Specifically, we used hierarchical latent space models (HLSMs; Sweet, Thomas, and Junker 2013) to analyze the directed networks elicited by our surveys. HLSMs are ideal for our analyses for several reasons. First, they allow us to estimate parameters across all schools

simultaneously; in this, they are similar to multilevel models often used with nested data. Furthermore, like multilevel models, HLSMs allow us to pool information across schools, since we assume that covariates included in the models have similar effects across schools. Finally, the models include latent space positions that implicitly control for structural aspects of networks, such as reciprocity and centrality, allowing for estimation of covariate effects (Hoff, Raftery, and Handcock 2002). These estimated latent space positions can be treated as a form of residual network structure not accounted for by covariates. One limitation is that HLSMs allow only for cross-sectional analysis of network data, so we analyzed each year's networks separately.

We implemented our HLSMs as follows:

$$log\frac{P(Y_{ijk}=1)}{1-P(Y_{ijk}=1)}=\beta_0+\beta_1X_{1ijk}+\ldots+\beta_8X_{8ijk}-|Z_{ik}-Z_{jk}|. \quad (1)$$

In this model, the dependent variable Y_{ijk} indicates a tie directed from staff member i to staff member j in school k. Z_{ik} and Z_{jk} are the latent space positions for staff members i and j, which control for structural aspects of each school's network that might affect the likelihood of a tie. X_{ijk} represents individual-, pair-, or network-level covariates; of these, the key independent variable is a measure of propinquity between school staff, which in some analyses was measured as the within-building walking distances between two staff members' workspaces; in other analyses, we measured this as the overlap between functional zones in the dyad.

X_{ijk} also includes a number of covariates that control for individual or dyadic attributes known to predict the likelihood of ties between school staff (Spillane et al. 2012, 2016). Panel B in Table 1 presents descriptive information on these covariates (for 2012 to 2013). At the individual level, controls for tie senders and receivers include an indicator for whether a staff member taught students in multiple grades; was assigned a leadership role, such as principal, assistant principal, coach, or grade-level leader; and number of years of experience in education (standardized within years). At the pair (dyad) level, we included a control for whether the dyad taught the same grade level, which prior research shows is a strong predictor of work-related ties among school staff (Spillane et al. 2012, 2016). At the network level, we controlled for network size, again standardized within year.

If school staff who taught the same grade level were located close together in a school building, the correlation of grade level and physical distance would confound our estimates of the effects of propinquity on the likelihood of ties. In our data, teaching the same grade level and walking distance were indeed negatively correlated, as might be expected; however, the magnitudes of these correlations were surprisingly small (although statistically significant), ranging from –.09 to –.12 across the four years. Functional zone overlap was also only slightly (although generally significantly) correlated with teaching the same grade level; correlations between these two measures ranged from –.03 to .13, depending on the year and locations used to define functional zones.

Roughly 13 percent of survey respondents did not list a room number on the survey, so we were unable to calculate walking distances or functional zone overlap for some dyads. We addressed these missing data in two steps. First, we manually entered missing room numbers using the job assignments respondents listed on the survey. Second, we used a multiple imputation procedure to impute walking distance or zone overlap for dyads for whom we did not have a room number for at least one member of the pair. To impute missing distances or zone overlap, we estimated a multiple regression equation for each school, predicting proximity from whether two staff members taught the same grade, held a leadership role, and taught multiple grades and the difference in their years of experience in education. Using the predicted values from this equation and the residual error, we sampled five different values to use for analysis, and we conducted our analyses separately using data sets with each of these five imputed values. Parameter estimates and overall inference did not differ much between these five data sets, so we present results from just one here. We also conducted our analyses using only complete case data, and the results were qualitatively similar to those conducted using the imputed data sets. We report results here from models that include imputed data.

Examining the endogeneity of proximity and ties.

Propinquity and ties would be endogenous if administrators' (or teachers') strategic

Table 2. Changes in Room Assignments and Walking Distance, Auburn Park, 2010 to 2013.

	Changes in room assignments (individual level)		Changes in walking distances (pair level)		
Year	% Changed room	*n*	% Change = 0 ft	% Change < 50 ft	*n*
2010 to 2011	30	179	50	69	2,432
2011 to 2012	24	214	62	78	3,358
2012 to 2013	25	208	59	76	3,182

Note: Limited to individuals who listed room numbers on the survey in both years (left panel) and to pairs who were not missing distance and who appeared in the data in both years (right panel).

decisions led to school staff who already interacted being assigned workspaces closer together. AP had a moderate amount—24 to 30 percent—of staff members change room assignments between years across the four years of our data (see left panel of Table 2). These room changes did not result in large changes in distances between pairs, however (see right panel of Table 2). Between two pairs of years, for example, over 75 percent of dyads moved less than 50 feet further apart from one another (between the third pair of years, this percentage was slightly less, at 69 percent). Across the years, the walking distance between half the dyads or more did not change at all. This lack of change in propinquity between years makes it challenging to control for prior-year proximity in our analyses, which is one potential way to address the endogeneity of proximity and ties. Instead, we conducted several additional analyses to examine the endogeneity of propinquity and interactions, which we will describe in detail in the Results section.

Qualitative data analysis. Our interview data analysis involved open and closed coding in two phases (Strauss and Corbin 1998). First, we closed coded all data for references to the who, how, what, and why of interactions about instruction. These "macrocodes," which served as our initial "sensitizing concepts" focusing our analysis, were broad enough to allow for themes to emerge from our interview data (Creswell 2007; Miles and Huberman 1994). We coded one third of the interviews to establish interrater reliability (Carey, Morgan, and Oxtoby 1996). We first coded one interview and then met to discuss commonalties and discrepancies; we then recoded the interview and again discussed differences. Once we achieved Kappa coefficients (Fleiss 1971, 1981) of .85 or greater, we coded four additional interviews; Kappa coefficients for these interviews ranged from .72 to .99. Using the report feature of NVivo 9, we generated reports by school and by position (e.g., principal, teacher) for each code in phase 1 to identify patterns. We then generated reports for the "why" code and open coded all references, identifying key patterns. For the purposes of this article, we extracted all references to propinquity from these reports and read them to identify themes.

RESULTS

Walking Distance and Work-related Interactions Among School Staff

Physical proximity, as measured by within-building walking distance, predicts work-related interactions among school staff. Across all four years of our study, as the physical distance between a pair of staff members increases, the likelihood of a tie between them decreases (see Panel A of Table 3). Moreover, this pattern holds for close colleague networks and for mathematics and language arts instructional advice networks. Furthermore, physical proximity influences staff interactions independent of teaching multiple grades, having a leadership position, years of experience in education, teaching the same grade, and network size—factors that prior work suggests are associated with having work-related interactions. The associations between walking distance and ties—measured in log odds units in the table—are similar in magnitude and significance across all four school years we examined. Although the estimates cannot be distinguished statistically, our estimates also suggest that walking distance is more strongly associated with ties

Table 3. Associations between Propinquity and Ties in Close Colleague, Mathematics, and Language Arts Networks, Auburn Park, 2010 to 2013.

Variable	2010	2011	2012	2013
Panel A: Walking distance				
Colleague networks	**–.437**	**–.387**	**–.383**	**–.329**
Math networks	**–.610**	**–.570**	**–.486**	**–.637**
Language arts networks	**–.458**	**–.494**	**–.548**	**–.549**
Panel B: Zone overlap				
Colleague networks				
Exit, restroom	**.257**	**.247**	**.319**	**.208**
Lunchroom, principal	**.294**	**.343**	**.296**	**.237**
Math networks				
Exit, restroom	**.239**	**.415**	**.239**	**.408**
Lunchroom, principal	**.372**	**.415**	**.324**	**.400**
Language arts networks				
Exit, restroom	**.352**	**.398**	**.339**	**.343**
Lunchroom, principal	**.383**	**.405**	**.351**	**.368**

Note: Estimates are from hierarchical latent space models that control for teaching multiple grades, leadership role, and years of experience in education for tie senders and receivers; at the dyad level, for teaching the same grade level; and network size. Bold estimates can be distinguished from zero with 95% confidence.

in mathematics networks than in either language arts or close colleague networks.

In terms of the magnitude of these findings, our estimates for 2013 suggest that if the workspaces of two staff members who had a 30 percent probability of having a close colleague tie were moved 78 feet further apart (one standard deviation of distance), their probability of having a close colleague tie would decrease to 24 percent. If these staff members moved 156 feet further apart (two standard deviations), their likelihood of a close colleague tie would drop to 18 percent. Figure 3 illustrates this relationship between walking distance and close colleague ties in 2013, using the coefficients from our HLSMs and controlling for the covariates in those models. The dotted diagonal line shows the probability of a close colleague tie between staff members if physical proximity had no effect on the likelihood of such ties; the solid and dashed lines show the probability of a tie between dyads if the walking distance between two staff members increased by one (solid line) or two (dashed line) standard deviations. These lines move closer to the diagonal dotted line toward the left or right of the figure, showing that dyads that were either very unlikely or very likely to have a tie to begin with were less influenced by their physical proximity than dyads that had more moderate likelihoods of a tie at the outset.

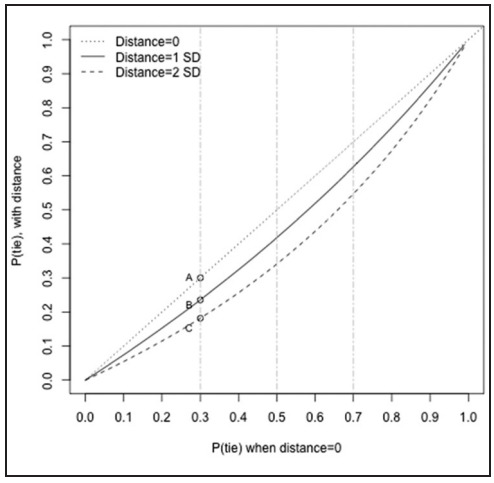

Figure 3. Effects of walking distance on close colleague ties, Auburn Park, 2013.

Note: Point A represents the baseline probability of a close colleague tie of 30 percent for a hypothetical pair of school staff. Point B represents the likelihood of a close colleague tie between this same pair if walking distance increased one standard deviation (approximately 78 feet); point C represents the likelihood of a tie if walking distance increased two standard deviations (approximately 156 feet).

Functional Zone Overlap and Work-related Interactions Among School Staff

Across all four school years, and for all three networks, the amount of overlap between the functional zones of two staff members positively predicted the likelihood of a tie between them, after controlling for the covariates in our models (see Panel B in Table 3). This relationship held regardless of how we defined the functional zone. Functional zone overlap had a smaller association with close colleague ties than with language arts or math ties, although once again these effects cannot be distinguished statistically. Finally, comparing Panels A and B in Table 3 shows that the magnitudes of the associations between functional zone overlap and ties were smaller than those between walking distance and ties.

Physical Proximity, Grade-level Assignments, and Interactions about Teaching

Analyses including interactions between same-grade indicators and our measures of propinquity find some evidence that propinquity is a stronger predictor of ties between staff members who teach the same grade than of ties between staff members who teach different grades (see Table 4). These findings were somewhat inconsistent across years and type of network, however. In 2012 and 2013, the associations between walking distance and language arts tie probability was stronger for same-grade pairs than for other pairs, although results for math and close colleague networks were inconsistent (see Panel A in Table 4). Results from interactions between zone overlap and a same-grade indicator were also inconsistent, although statistically significant results were all positive and large in magnitude. This suggests that, at least in some cases, propinquity matters more for within-grade ties than for ties outside grade levels.

Examining the Endogeneity of Physical Proximity and Ties

To examine whether proximity and ties were endogenous, we conducted several additional analyses. First, we examined whether having a tie the prior year predicted two staff members moving closer to one another in the following year. To do this, we fit an ordinary least squares regression model at the pair level, using change in walking distance between the pair as the outcome and a dummy variable for having a prior-year tie as the predictor, clustering standard errors at the school level to account for the grouping of staff into schools.[4] Having a tie in year $t - 1$ did not predict moving closer to one another in year t, or an increase in functional zone overlap in year t, for any of the three pairs of years we examined. In one pair of years (2012–2013), having a tie in the prior year was significantly associated with an increase in walking distance (i.e., moving further apart) as well as a decrease in zone overlap, suggesting that having a prior-year tie was associated with moving further apart in the building. Although these analyses examine the relationship between changes in proximity and ties over a two-year period and do not account for associations that might have occurred earlier, taken together, they suggest that pairs that had ties the prior year did not move closer to one another the following year and that—at least in the short term—endogenous choice of locations does not appear to be driving our results.

Our second analysis compares dyads that include a staff member new to the field of education to dyads that do not have such a staff member. If both respondents in a dyad had prior education experience, they could have previously interacted, and this interaction could have led to their being located near one another in their school buildings. Pairs that include a staff member who was entirely new to the field of education, however, were unlikely to have had an opportunity to establish a prior tie.[5] Table 5 presents results of these descriptive analyses for 2012 to 2013.[6] (For purposes of this analysis, we counted a dyad as having a tie if they had a close colleague, mathematics, or language arts tie.) Panel A of Table 5 shows that among dyads that did not have a staff member who was new to education, dyads that had a tie were located closer together in the building and had greater zone overlap than did dyads that did not have a tie, as we would expect given the findings of our social network models. Panel B, however, shows that the same was true for dyads that included at least one staff member new to education. This again suggests that endogenous choice of location within buildings does not provide a central explanation for our results.

Our third analysis is identical to the main analyses presented earlier, except it includes a control

Table 4. Associations between Propinquity and Ties in Close Colleague, Mathematics, and Language Arts Networks, Including Interactions with Same Grade, Auburn Park, 2010 to 2013.

Variable	2010	2011	2012	2013
Panel A: Walking distance				
Colleague networks				
Walking distance	**–.468**	**–.327**	**–.408**	**–.195**
Walking Distance × Same Grade	.058	–.099	.051	**–.251**
Math Networks				
Walking distance	**–.538**	**–.632**	**–.314**	**–.594**
Walking Distance × Same Grade	–.113	.096	**–.265**	–.060
Language arts networks				
Walking distance	**–.571**	**–.509**	**–.317**	**–.354**
Walking Distance × Same Grade	.152	.021	**–.341**	**–.284**
Panel B: Zone overlap				
Colleague networks				
Exit, restroom	**.245**	**.215**	**.273**	**.146**
Exit, Restroom × Same Grade	.033	.073	.091	.147
Lunchroom, principal	**.257**	**.234**	**.306**	.013
Lunchroom, Principal × Same Grade	.050	**.216**	–.029	**.442**
Math networks				
Exit, restroom	**.241**	**.412**	.108	**.298**
Exit, Restroom × Same Grade	.004	–.020	.216	.160
Lunchroom, principal	**.397**	**.208**	.034	.110
Lunchroom, Principal × Same Grade	–.036	**.304**	**.418**	**.416**
Language arts networks				
Exit, restroom	**.298**	**.415**	**.213**	**.283**
Exit, Restroom × Same Grade	.075	–.035	**.213**	.077
Lunchroom, principal	**.420**	**.344**	.090	.059
Lunchroom, Principal × Same Grade	–.042	**.103**	**.372**	**.438**

Note: Estimates are from hierarchical latent space models that control for teaching multiple grades, leadership role, and years of experience in education for tie senders and receivers; at the dyad level, for teaching the same grade level; and network size. Bold estimates can be distinguished from zero with 95% confidence.

Table 5. Differences in Physical Proximity between School Staff With and Without A Tie, for Dyads That Did and Did Not Include a New Staff Member, Auburn Park, 2012 to 2013.

	A. Dyads that did not include a new staff member			B. Dyads that included at least one new staff member		
Variable	Tie	No tie	Difference	Tie	No tie	Difference
Walking distance	169	239	–70***	159	220	–61***
Exit, restroom	272	218	54***	295	243	52**
Lunchroom, principal	373	328	45***	404	342	62***
n, dyads	685	4,229		59	491	

Note: Distances are measured in feet.
**$p < .01$. ***$p < .001$.

for whether a pair had a prior-year tie ($t - 1$), therefore focusing on whether physical proximity was associated with the creation of new ties, as opposed to the existence of ties (see Table 6).[7] The results demonstrate that both walking distance and functional zone overlap are strong predictors

Table 6. Associations between Propinquity and New Tie Formation in Close Colleague, Mathematics, and Language Arts Networks, Auburn Park, 2011 to 2013.

Variable	2011	2012	2013
Panel A: Walking distance			
Colleague networks	**–0.308**	**–0.205**	**–0.200**
Math networks	**–0.576**	**–0.334**	**–0.539**
Language arts networks	**–0.406**	**–0.401**	**–0.431**
Panel B: Zone overlap			
Colleague networks			
Exit, restroom	**0.287**	**0.243**	0.083
Lunchroom, principal	**0.303**	**0.186**	**0.131**
Math networks			
Exit, restroom	**0.413**	**0.243**	**0.278**
Lunchroom, principal	**0.233**	**0.195**	**0.163**
Language arts networks			
Exit, restroom	**0.331**	**0.285**	**0.182**
Lunchroom, principal	**0.276**	**0.241**	**0.167**

Note: Estimates are from hierarchical latent space models that control for teaching multiple grades, leadership role, and years of experience in education for tie senders and receivers; at the dyad level, for teaching the same grade level and prior ties; and network size. Bold estimates can be distinguished from zero with 95% confidence.

of the formation of new ties; school staff were more likely to form new ties with colleagues they were located closer to in their buildings or with staff whom they were more likely to encounter during the day. The magnitudes of the coefficients in Table 6, although generally smaller than those in Table 3, are still substantial, suggesting that proximity was associated not only with the presence of ties but also with the creation of new ties, providing additional reassurance that the endogeneity of proximity and ties does not explain our results.

Our final set of analyses explores whether *changes* in proximity between year $t - 1$ and year t predict the formation of new ties. As with the previous analyses, these analyses include a control for having a prior-year tie; however, these analyses use a measure of the change in proximity (walking distance or zone overlap) between year $t - 1$ and year t as the measure of propinquity. We found that changes in walking distance or zone overlap between year $t - 1$ and year t did not predict the formation of new ties in any of the years we examined. These analyses may be limited by the relatively small amount of change in proximity from year to year (see Table 2), rendering it difficult to detect associations between changes in proximity and the formation of new ties.

Potential Mechanisms by Which Propinquity Affects Staff Interactions about Teaching

On the basis of our analysis of interview data, we argue that physical proximity enables work-related ties by reducing the costs involved in making a connection *and* increasing exposure to colleagues, which creates opportunities for unplanned chance encounters (Small 2013). With no interviewer prompting, 27 of the 33 interviewees (82 percent) volunteered physical proximity as a reason for interacting with a colleague, typically one of several explanations offered. Some staff reported that physical proximity reduced the cost of making a connection. Explaining her interaction with a colleague about mathematics, Clarissa, a fifth-grade teacher at Kingsley, remarked that "because we're next door to each other . . . because we have that connecting door it's just easier than [going] across the hall."[8] Clarissa's comment captures how physical proximity enables work-related interactions by reducing the effort involved in reaching out to a colleague, even when the differences in distance are small. Similarly, Rachel, a kindergarten teacher at Chamberlain, explained how physical proximity accounted for her interactions with one of her fellow kindergarten teachers but not others:

> I'm right next door to one of my [colleagues], our kindergarten team is kinda spread out but I'm right next door to [Arianna] and she teaches kindergarten. She's amazing at math too. [laughs] And so she's a given that I always, I always go to her first . . . it's kinda easy to be like "OK, so my kids are doing this today in math."

Rachel described how physical proximity made it easier to seek out that colleague than other teachers, even others who taught the same grade level. Rachel's account is consistent with our earlier analyses on the relationship between propinquity, same-grade assignment, and work-related interactions, which show that propinquity is an important predictor of interaction among teachers in the same grade.

School leaders' and teachers' accounts also suggest that propinquity enables interactions by creating opportunities for chance encounters. Joanne, a sixth-grade teacher at Bryant, said that "it's casual it's just, you see them . . . because it's more like in passing . . . hallways." Carol, a first-grade teacher at Bryant, explained that

> just before each unit we [other teachers in her grade level] sit down and we talk about what, what are the objectives, what do the students have to learn, what activities can we do to ensure . . . success of all that . . . we were doing a graphing activity and the students graphed and we [other teachers in her grade level] were discussing the graph out in the hallway and um, she happened to walk by and she just kind of sat down and joined us and so then I just asked her . . . some feedback on, you know, how my conversation went and what I could have [done] to . . . deepen the kids' understanding."

Carol said that formally organized meetings with colleagues teaching the same grade are important in supporting interactions about teaching, but she noted that proximity is also critical in enabling her to engage in unplanned informal exchanges.

Joanne's and Carol's accounts suggest that being physically close enables interactions, because it increases the likelihood of bumping into a colleague by chance. Mary, a fifth-grade teacher at Chamberlain, also captured how physical proximity enables informal exchanges, noting, "It happens on such an informal basis and a formal basis. I mean we can walk down the hallway and get into a conversation about math. And it could be something from something a student said or did or a way of solving a problem." Similarly, Rebecca, a fifth-grade teacher at Chavez, said that a colleague she interacts with frequently about mathematics is "in the room right next door to me so" so we interact "in the hall all the time." Courtney, a literature facilitator at Chavez, described how propinquity enables her to interact with a colleague about mathematics "very casually . . . if something comes up or if I happen to see him and I bop in his room quite often. . . . We used to laugh and say they were drive-by, but actually they're walk-by conversations. Again it, it's as an as needs basis."

Proximity in the form of functional zone overlap also facilitated these "walk-by conversations," as Karen, a first-grade teacher at Chavez, captured when she noted that a colleague's

> room is kind of on the curve as you go down to the lounge, so in my, in my planning time when I go to check my mailbox and come back and I've seen the kids on the floor and I see that they're interacting, that's kind of when I kind of just popped in, peeked in.

Reflecting on interaction patterns among staff at her school, Kelly, the principal at Chamberlain, said,

> I will hear teachers talk informally in the hallway about math instruction. And they do about a lot of instruction, not just math. But I will see where there will be little sidebars you know all the time with teachers saying you know, "I did this lesson and . . . blah-blah-blah."

Georgia, the principal at Bryant, recalling her time working in a district school, remarked that "most of my conversations with people were very, what I would consider to be informal, they weren't you know, 'I'd like to talk to you about' and so we schedule a time. It was more informal types of conversations."

School staff members generally referred to propinquity alongside other explanations for work interactions, especially aspects of the formal school

organization. Opportunities for interactions about teaching made possible by propinquity appeared to work in conjunction with those made possible by the formal organization. John, a second-grade teacher at Chavez, noted how both formal and informal exchanges were key to his interactions with colleagues about mathematics:

> For sure one of them is more formal because that's like our planning time and so we're discussing what's coming up, how we're going to, how we're going to do it as a [grade-level] team, math . . . then other times they're just more informal and Betty or Jennifer will come and just ask me a question.

As Carol, a first-grade teacher at Bryant, explained with respect to grade-level team meetings and professional learning community (PLC) meetings, "We do that as we plan, but yet we're always constantly, we, on a day-to-day basis I feel like we almost talk, 'How did that go in math?' or, 'I did this and this worked great.' And so we're always just sharing ideas." Similarly, Katie, a sixth-grade teacher at Chavez, said that while formal PLC and grade-level team planning meetings allow teachers to plan lessons, the informal exchanges enabled by propinquity are critical to problem solving about how best to teach these lessons:

> Well actually math is first thing in the morning for us, we have math from 8:20, 8:30 depending on when we get rolling, to 9:30 and then at 9:30 we go to specials . . . we go to specials at the same time, so since that's fresh in my mind if something happened in math or didn't happen in math the way I wanted it to, you know, she'll pop into my room and we'll just chit chat for a little bit and that, and math will come up. Or I'll pop into her room and say, "Oh my God, you'll never guess what happened in math today."

Carol's and Katie's accounts suggest that interactions with colleagues about teaching that take place as part of formal organizational routines continue through informal and unplanned everyday exchanges. Furthermore, their accounts capture how informal interactions enabled by propinquity extend the interactions enabled by the formal organizational infrastructure. Their accounts also suggest that while complementing formal interactions, these informal interactions serve a unique purpose, providing teachers an opportunity to discuss problems and dilemmas soon after they occur, while they are still "fresh in the mind," potentially enabling teachers to develop particular knowledge and skills about teaching.

DISCUSSION AND CONCLUSIONS

Our work offers new evidence on the effects of relatively small distances on work-related intraorganizational interactions (Marmaros and Sacerdote 2006). On the basis of these analyses, we argue that research on the sociology of the school workplace should not ignore propinquity and should instead pay close attention to the "elephant in the schoolhouse": the role of propinquity in staff interactions about teaching. The "spatial configurations of social life" are consequential (Giddens 1984:363), even within modest-sized elementary schools, but too often they are ignored or treated implicitly in studies of staff interactions about teaching. Research on staff interactions about teaching tends to focus on the importance of norms and formal organizational arrangements, but our analysis documents that physical arrangements also structure these interactions in important ways. Furthermore, our use of social network models enables us to isolate the effects of propinquity from other factors that often coincide with propinquity in school organizations—particularly, grade-level assignments—and are also predictive of teachers' interactions about their work. We also find that propinquity may work in concert with aspects of the formal school organization, such as grade-level assignments. Ignoring physical proximity in our efforts to estimate the predictors of social interactions in schools will likely generate an incomplete picture of the factors that enable interactions among school staff. For scholars researching the school workplace in general, and the transformation of teaching from an isolated practice to a collective practice in particular, physical proximity merits explicit attention.

Theorizing *how* propinquity influences teachers' interactions with peers about teaching, our article makes several contributions to the literature on

the sociology of the school workplace and teachers' work. Our account advances our understanding of how propinquity matters by demonstrating that walking distance is just one way of measuring propinquity in the school workplace. Interestingly, we find that walking distance is a stronger predictor than functional zone overlap of work-related social interactions, a finding that contrasts with prior work that used similar measures in a different setting (Kabo et al. 2015). This prior work examined the relationship between propinquity and ties in a different organizational context—scientific research organizations—so the difference may reflect the particular organizational arrangements of elementary schools.

Drawing on interview data and the literature on the sociology of teaching, we theorize that the informal interactions about teaching that propinquity enables may not just extend or complement those afforded by formal organizational arrangements (e.g., grade-level teams) but may also provide a unique opportunity for staff to interact about instructional issues close to the time when teachers are actually grappling with them in their classrooms. Propinquity may therefore allow for different kinds of interactions than those afforded by formal organizational arrangements, such as grade-level meetings. Research on teaching in general, and the sociology of teaching in particular, reminds us that such interactions are key in schools, as teaching is complex, unpredictable, and knowledge-intensive work (Cohen 1988; Rowan 1990). Under these circumstances, opportunities for ongoing knowledge development about teaching is critical for teachers to adapt their teaching practice to particular emerging situations (Frank et al. 2011; Zhao and Frank 2003). Formal meetings enable some of this knowledge development among teachers; yet teachers often encounter novel and challenging classroom situations, and their efforts to solve these dilemmas can benefit from more immediate discussion with peers. By reducing the cost involved in an interaction or increasing the likelihood of chance encounters, propinquity provides opportunities for teachers to develop this sort of knowledge when needed, without a great deal of forethought. Understanding propinquity is thus key to understanding the relations between formally and informally structured school interactions.

Our analysis has implications for future research and practice concerning the school workplace. With respect to research, our analysis suggests the importance of understanding not only whether propinquity matters to school staff interactions but also how propinquity works in interaction with aspects of the formal school organization to enable or constrain staff interactions. Future work might examine how propinquity works in conjunction not only with aspects of the formal organization, such as grade-level assignment or participation in formal organizational routines, but also with school norms. A critical component of this work will involve not only measuring these interaction effects but understanding how these various aspects of the school workplace combine to influence interactions among staff. Such work will necessitate mixed-method designs.

Similarly, our efforts to understand the role of homophily based on individual characteristics, particularly race, were limited due to the homogeneity of the teacher workforce in the district we studied. Understanding interactions between race, propinquity, and formal organizational infrastructure will have to await work in more diverse districts. Teachers' propensity to interact with colleagues of the same race may be moderated by propinquity; perhaps, for example, teachers of similar race are more likely to walk greater distances to interact with one another. We suspect, however, that any such interactions may depend on the school's overall racial composition, particularly, the extent of racial diversity among the staff. One framework for thinking about this work is in terms of the influence of propinquity in interaction with the assortative and relational factors that predict ties between individuals (see Rivera et al. 2010), with particular attention to how these various factors work together to influence staff interactions. In demonstrating that interactions among staff are both enabled and constrained by the physical spaces in which they occur, we make the case for including propinquity in such studies.

Our findings also have some implications for educational practice. Specifically, school buildings should be designed to promote interaction by minimizing the walking distances between classrooms and maximizing the overlap of staff members' functional zones. An important consideration for such design work (and future research), however, will be whether it is the relative proximity or the absolute proximity between workspaces that predicts ties. If proximity relative to other distances in a school is what matters, altering the design of school buildings could affect which staff

members talk to one another about their work but may not affect the overall amount of interaction that takes place.

Our findings also have implications for the assignment of school staff to workplaces in the school buildings that already exist. In elementary schools, staff workplaces—even those of "master" teachers, instructional coaches, or school leaders—are often determined with limited thought to how propinquity structures interactions among staff. Instead, staff members are often assigned to workspaces based on grade-level assignments, seniority, or available space. Such practical considerations are important and are often demanded by the realities of schools; however, our findings argue for careful consideration when assigning school staff to workspaces, as physical proximity appears to play a significant role in who talks to whom about instruction. By assigning "master" teachers and individuals in leadership positions to workspaces that maximize their physical proximity to all staff, school leaders may help improve the instructional knowledge of their entire staff. School leaders might also consider propinquity when distributing their staff throughout the school building, so as to maximize the opportunities staff have to interact with exemplary teachers, teachers of other grade levels, or staff with particular areas of expertise.

Finally, we did not expect to find such small correlations between proximity measures and grade-level teaching. We had assumed that classrooms are arranged by grade levels in schools, but our account suggests some caution in making this assumption. Exploring the schools' floor plans, we noticed that the prevalent pattern is for "bands" of grades (e.g., primary grades, upper grades) to be clustered together, which sometimes means the same grades are not located right next to one another. This may in part be a function of staff transitions over time; if a second-grade teacher leaves the school, for example, a new teacher may be hired and assigned to teach first grade or kindergarten, but to minimize disruption, this new teacher is assigned to the room vacated by the second-grade teacher. In short, the physical arrangement of grade levels may not be as purposeful or planned as we might expect. Furthermore, the weak correlations between propinquity and grade level may indicate that physical colocation is a rather crude measure of propinquity. School leaders may need more nuanced metrics and heuristics for thinking about propinquity, instead of relying on the shorthand of physical clustering of grades in their buildings. Of course, it is important to keep in mind that the physical colocation of bands of grades may be important for supporting conversations among adjacent-grade-level teachers, which is important for the horizontal alignment of curriculum (Bidwell 1965). Although any approach that school leaders take to assigning staff to workspaces will necessarily involve trade-offs, our analyses suggest these decisions should be made carefully, as they could have substantial effects on the teaching and learning taking place in schools.

Appendix A. Comparison of Functional Zone Overlap Using Various Definitions of Functional Zones.

Locations	Mean overlap	Standard deviation of overlaps	Minimum overlap	Maximum overlap
Copier, exit	210	142	0	795
Copier, lunchroom	294	114	92	895
Copier, principal	155	101	19	635
Copier, restroom	137	88	26	721
Exit, lunchroom	326	158	0	852
Exit, principal	231	135	14	706
Exit, restroom	222	145	26	678
Lunchroom, principal	302	106	136	898
Lunchroom, restroom	280	84	127	872
Principal, restroom	171	83	57	724

Note: Statistics are for all 14 Auburn Park schools combined (locations, $N = 573$). Zone overlap is measured in feet.

Appendix B. Correlations between Functional Zone Overlap Measures, Auburn Park.

Variable	Copy, exit	Copy, lunch	Copy, prin.	Copy, rest.	Exit, lunch	Exit, prin.	Exit, rest.	Lunch., prin.	Lunch, rest	Prin., rest
Copy, exit	1.00									
Copy, lunch.	0.33	1.00								
Copy, prin.	0.56	0.50	1.00							
Copy, rest.	0.69	0.64	0.65	1.00						
Exit, lunch	0.76	0.61	0.32	0.66	1.00					
Exit, prin.	0.96	0.27	0.59	0.66	0.76	1.00				
Exit, rest.	0.91	0.20	0.41	0.71	0.74	0.90	1.00			
Lunch, prin.	0.26	0.92	0.51	0.66	0.58	0.30	0.19	1.00		
Lunch, rest.	0.29	0.78	0.45	0.61	0.53	0.27	0.29	0.77	1.00	
Prin., rest.	0.51	0.47	0.75	0.86	0.42	0.56	0.58	0.57	0.54	1.00

Note: Statistics are for all 14 Auburn Park schools combined (locations, $N = 573$). Lunch. = lunchroom; prin. = principal; rest. = restroom.

RESEARCH ETHICS

This research was approved by the Institutional Review Board of Northwestern University and was therefore conducted in accordance with the ethical standards articulated in the 1964 Declaration of Helsinki and its subsequent amendments as well as Section 12 ("Informed Consent") of the American Sociological Association's Code of Ethics. All human subjects involved in this research gave their informed consent prior to participation in the research. Adequate steps were also taken to protect participants' confidentiality, including the use of pseudonyms for districts, schools, and individual school staff members; storage of data on secure, password-protected servers; and access to data limited to the researchers.

ACKNOWLEDGMENTS

We gratefully acknowledge Kelsey Rydland and Yongha Hwang for their generous assistance in creating the data utilized in this article, John Wylie and Shih-Yung Huang for research assistance, Melissa Ortiz for editorial assistance, and Simone Ispa-Landa, Tim Hallet, the three anonymous reviewers, and the editor for their very helpful feedback that contributed immensely to the final draft. We are especially grateful of the teachers and school leaders who responded to our survey. All opinions, findings, and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of any of the funding agencies.

FUNDING

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Work on this article was supported by the NebraskaMATH Study (http://www.distributedleadership.org/projects.html) at Northwestern University and University of Nebraska–Lincoln, funded by research grants from the National Science Foundation (DUE-0831835). The work was also supported by the Distributed Leadership Studies (http://www.distributedleadership.org) funded by research grants from the National Science Foundation (REC–9873583, RETA Grant No. EHR–0412510). Northwestern University's School of Education and Social Policy and Institute for Policy Research also supported this work. All opinions and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of any funding agency.

NOTES

1. In all 14 Auburn Park schools, workspaces were located on a single floor, so cross-floor paths (using staircases or elevators) did not have to be traced or modeled.
2. Given the findings of prior research, we would expect greater functional zone overlap between two staff members to be associated with *increased* likelihood of a tie, whereas we would expect greater walking distance to be associated with *decreased* likelihood of a tie. Walking distance and functional zone overlap were indeed negatively correlated in our data (e.g., with correlations ranging from –.45 to –.58 in 2013, depending on the specific locations used to determine individuals' functional zones).
3. We thank Yongha Hwang for generously providing the Python code that computed the overlap of functional zones between dyads and for his guidance in implementing this code.

4. Because of the significant amount of staff turnover from year to year in Auburn Park (only 33 to 43 percent of possible pairs observed in year $t-1$ remained as potential pairs in year t during the three pairs of years we examined), we were unable to examine the relationship between ties and changes in proximity over more than two years. This analysis therefore does not rule out the possibility that ties from prior years explain changes in propinquity; however, out results provide some suggestive evidence on the relationship between ties and changes in proximity over the short time frame we are able to examine with our data.
5. Staff members could have worked together as preservice (student) teachers or in some other capacity or setting; however, it is difficult to imagine a circumstance in which all or most dyads that include a staff member new to education had some prior connection.
6. Because of the small number of dyads that contain new staff members, we were unable to conduct a separate social network analysis for those dyads. Results for other school years were similar, so we report only the 2012–2013 school year here.
7. Because these analyses control for whether a dyad had a prior-year tie, they are necessarily limited to pairs that appear in the data in consecutive years. Due to the significant amount of staff turnover in Auburn Park schools (19, 23, and 15 percent of staff left our sample between each pair of years, respectively), the sample size for these analyses was limited. The significant amount of staff turnover also limited our ability to implement other longitudinal social network methods.
8. All staff and school names are pseudonyms.

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