Teacher Advice-seeking: Relating Centrality and Expertise in Middle School Mathematics Social Networks

Cover Page

Article Description: This study investigates how expertise and formal role relate to who is sought for advice about mathematics instruction, as measured by centrality, in 30 urban middle schools. Multiple analyses showed that: (1) coaches are more central than teachers who are more central than administrators, (2) teachers with greater expertise are more central, (3) teachers are more likely to nominate a coach if they perceive the coach to have expertise and be evaluative, and (4) administrators are rarely nominated as sources of advice about middle school mathematics instruction.

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Structured Abstract

Background/Context:

Teachers' relationships with principals, instructional coaches, and other teachers have important implications for the improvement of their instructional practice and student learning. In particular, teachers who access content-specific instructional expertise through their social networks are more likely to exhibit and sustain evidence of instructional improvement; teachers who seek advice from colleagues with knowledge of both content and pedagogy have evidenced growth in their own knowledge and improved classroom instructional practice.

Purpose/Objective/Research Question/Focus of Study:

In this paper, we extend the literature by examining how formal role relates to the relationship between expertise and advice-seeking in the context of urban middle school mathematics teachers' social networks. Specifically, we first explore how network centrality varies across formal role group (i.e., teacher, instructional coach, and principal/assistant principal), and second, we investigate how centrality relates to expertise within each formal role group.

Research Design:

We draw on a variety of data sources taken from a four-year observational study of a sample of 30 schools and 533 teachers, coaches, and administrators in four large urban school districts. In particular, we rely on data from a network survey to document teachers' advice-seeking behaviors, and we draw on the broader data set to document formal role and measures of expertise within each role group.

Findings/Results: The main findings are: (1) coaches were significantly more central than teachers who are significantly more central than administrators, (2) teachers with greater expertise were more central, (3) while coach expertise was not related to centrality, teachers were more likely to nominate a coach if they perceived the coach to have expertise and be evaluative, and (4) administrators were rarely nominated.

Conclusions/Recommendations:

Findings indicate that teachers are accessing information from those with expertise and experience, which suggests that advice-seeking among teachers may be self optimizing. Furthermore, teachers' advice-seeking seems to be shaped both by their efforts to access expertise and in response to accountability pressures. This creates a cautionary tale against the misalignment of formal role and expertise. Our findings suggest that those in a social network whose social status is elevated to the formal role of coach are more sought out for advice, particularly if they are perceived to have evaluative power. This can inform what administrators can expect of teachers' informal advice seeking as well as how advice-seeking patterns are likely to shift if a teacher is made a coach.

Executive Summary

Introduction

Teachers' relationships with principals, instructional coaches, and other teachers have important implications for the improvement of their instructional practice and student learning. These relationships, and the social networks in which they are situated, can greatly influence efforts to implement and sustain instructional change at scale (Coburn & Russell, 2008; Coburn, Russell, Kaufman & Stein, 2012). In particular, teachers who access content-specific instructional expertise through their social networks are more likely to exhibit and sustain evidence of instructional improvement (Sun, Wilhelm, Larson, & Frank, 2014; Coburn et. al., 2012); teachers who seek advice from colleagues with knowledge of both content and pedagogy have the potential to raise the level of their own knowledge and improve their classroom practice. In spite of evidence supporting the importance of accessing instructional expertise through social networks, much of the literature on teachers' advice-seeking behavior focuses on the ways in which homophily shapes teachers' networks (e.g., Moolenaar, 2012). In other words, teachers tend to interact with peers who share common demographic characteristics (gender, age, race/ethnicity) or experiences (e.g. teaching same subject/grade level).

While some prior research has explored teacher advice seeking patterns, few studies have examined teacher advice seeking among principals, assistant principals, instructional coaches, and other teachers, and the relationship of this advice seeking to expertise in the context of schools undergoing systematic instructional reform. Therefore, we extend the literature by examining how formal role relates to the relationship between expertise and advice seeking in the context of urban middle school mathematics teachers' social networks. Specifically, we pose the following research questions: In the context of middle school mathematics social networks, (1) What is the relationship between centrality and formal role group? and (2) What is the relationship between centrality and expertise within different role groups? This study offers insight into the relationship between informal and formal aspects of school organizations, as it allows us to see how formal structure (role group) relates to informal interactions (advice-seeking behavior) in the context of accessing and perceiving expertise.

Methods

The data for this study were collected as part of a larger, four-year project, which began in the 2007-2008 school year. This larger study was designed to address the question of what it takes to improve the quality of middle-grades mathematics instruction, and thus student learning, at scale. The project worked with 30 schools across four large, urban school districts attempting to achieve a vision of high quality mathematics instruction that was broadly compatible with the National Council of Teachers of Mathematics' (2000) recommendations. In order to collect data on the social network in each school, all mathematics teachers, principals, assistant principals that oversee mathematics, and mathematics instructional coaches in each of these schools were sent a network survey that asked, "During this school year (including last summer), is there a person you have turned to for advice or information about teaching mathematics?" Additional data were collected from administrators, coaches, and a randomly selected sample of about 5 mainstream mathematics teachers per school, which included 1) an online survey, 2) an assessment of mathematical knowledge for teaching, and 3) videotaped classroom instruction to assess instructional quality. Across the three years of data used in this analysis, network survey responses were collected from 965 participants in 30 schools, which included 132 principal and assistant principal responses, 73 instructional coach responses, and 760 teacher responses. However, many participants participated during multiple years. Taking repeat participants into account, our sample contained 79 unique principals and assistant principals, 50 unique coaches, and 407 unique teachers.

Our main variable of interest for this study is a person's centrality in their school's social network, as this enabled us to identify who was most heavily sought out for advice about mathematics instruction and then relate this to formal role and measures of expertise. To calculate the centrality of each person within the school's social network, we took the ratio of the number of times that a person was nominated from within the school to the number of people in the school who could have nominated the person. Our analyses draw on four primary measures of expertise: years of experience, instructional quality (IQA), mathematical knowledge for teaching (MKT), and gains in student achievement. We employ multilevel modeling for our analyses; specifically, each model is a three level model with level 1 containing individuals in a certain year, level 2 accounting for individuals that may appear in multiple years, and level 3 encompassing the 30 schools in our sample.

Results

The main findings were that: (1) centrality varies by role group: coaches were significantly more central than teachers who are significantly more central than administrators, (2) teachers with greater expertise were more central, (3) while coach expertise was not related to centrality, teachers were more likely to nominate a coach if they perceive the coach to have expertise and be evaluative, and (4) administrators were rarely nominated.

Our first research question examines differences in mean centrality across the three role groups: teachers, coaches, and administrators. Administrators were significantly less central than teachers, and instructional coaches were significantly more central than teachers. On average, coach centrality tended to be 26% higher than that of teachers, and administrator centrality tended to be 7% lower than that of teachers. When looking only at teachers, three of the measures of expertise were significantly associated with a teacher's centrality while controlling for all other effects in the model: mathematical knowledge for teaching, years experience teaching mathematics, and student achievement gains. Specifically, more knowledge for teaching, more experience, and greater gains in student achievement were all related to gains in centrality.

Coach expertise was largely unrelated to greater levels of coach centrality; however, 98% of coaches received at least one nomination. As such, we wanted to understand what differentiated teachers who went to a coach from those others did not. Teachers who perceived the coach to have higher levels of expertise were more likely to nominate a coach. In addition, teachers who perceived coach visits to be evaluative were significantly more likely to nominate a coach as a source of advice about mathematics instruction. Finally, nearly 73% of administrators in our sample had a zero centrality, which means that none of the mathematics teachers in these administrator's schools reported seeking advice on mathematics instruction from them. Further, none of the available measures of expertise and experience were significantly associated with administrator centrality.

Discussion

To improve instruction at scale, schools and districts need to provide substantial support to teachers, and schools' school social networks are one mechanism through which instructional innovations are interpreted and propagated (Frank, Zhao, & Borman, 2004; Penuel, Sun, Frank,

& Gallagher, 2012). Our findings support the idea that teachers are accessing information from those in the network with expertise and experience. The finding that teachers seek out other teachers who have expertise suggests that advice seeking among teachers is in some ways self optimizing. The strength of the relationship between student achievement gains and centrality suggests that teachers are explicitly aware of which of their peers are effective at getting their students to make gains on the tests that matter, and that teachers' advice seeking behaviors are shaped by accountability pressures. This claim is strengthened by the relationship between teachers' perceptions of coach observations as evaluative and the likelihood that a teacher will turn to a coach for instructional advice. Taken together, this suggests that teachers' advice seeking is shaped both by their efforts to access expertise and in response to accountability pressures. This creates a cautionary tale against the misalignment of formal role and expertise. Our findings suggest that those in a social network whose social status is elevated to the formal role of coach are more sought out for advice, particularly if they are perceived to have evaluative power. This can inform what administrators can expect of teachers' informal advice seeking as well as how advice-seeking patterns are likely to shift if a teacher is made a coach.

Introduction

A central quandary in education for researchers, practitioners, and policy makers is the question of how to improve teaching and learning at scale. Teachers' relationships with principals, instructional coaches, and other teachers have important implications for the improvement of their instructional practice and student learning (e.g., Sun, Wilhelm, Larson, & Frank, 2014; Frank, Zhao, & Borman, 2004; Goddard, Goddard & Tschannen-Moran, 2007). These relationships, and the social networks in which they are situated, can greatly influence efforts to implement and sustain instructional change at scale (Coburn & Russell, 2008; Coburn, Russell, Kaufman & Stein, 2012). In particular, teachers who access content-specific instructional expertise through their social networks are more likely to exhibit and sustain evidence of instructional improvement (Sun, Wilhelm, Larson, & Frank, 2014; Coburn et. al., 2012); teachers who seek advice from colleagues with knowledge of both content and pedagogy have the potential to raise the level of their own knowledge and improve their classroom practice. In spite of evidence supporting the importance of accessing instructional expertise through social networks, much of the literature on teachers' advice-seeking behavior focuses on the ways in which homophily shapes teachers' networks (e.g., Moolenaar, 2012). In other words, teachers tend to interact with peers who share common demographic characteristics (gender, age, race/ethnicity) or experiences (e.g. teaching same subject/grade level). However, few studies have related specific forms of expertise, such as knowledge of content and how to teach that content, to teachers' advice-seeking behavior.

By exploring who teachers interact with on matters of instruction and how expertise and formal role relate to that advice-seeking, we improve our understanding of instructional leadership in schools, which functions as an important aspect of efforts to improve instruction at scale (Hallinger, 2005; Bryk, Sebring, Allensworth, Luppescu & Easton, 2010; Cobb & Jackson, 2011). While we do not measure instructional improvement directly in this study (e.g. by exploring changes in instruction or student outcomes on standardized assessment across districts), we do examine the teacher networks in schools situated in districts engaged in deliberate efforts to improve the quality of middle grades mathematics instruction[1] thus providing a rich context for our study. District and school leaders designate individuals into formal instructional leadership roles, such as principals, assistant principals, and instructional coaches, to support instructional improvement (Leithwood, Patten, & Jantzi, 2010). Some studies have investigated how the centrality of formal leaders (i.e., principals and instructional coaches), which is an indicator of how often a person is sought out for instructional advice in their school, links to school outcomes and reform efforts (Atteberry & Bryk, 2010; Friedkin & Slater, 1994). However, teachers also seek advice from their peer teachers who may not have a formal role in instructional support (Moolenaar, 2012).

For policymakers and practitioners looking to improve instruction across a system, it is fruitful to consider the sources of advice and instructional support teachers have available. If district and school leaders have a sense of who is sought out for advice on instructional issues, then they can more strategically position expertise within the school network. While some prior research has explored teacher advice-seeking patterns, few studies have examined teacher advice-seeking of principals, assistant principals, instructional coaches, and other teachers and the relationship of this advice-seeking to expertise in the context of schools undergoing systematic instructional reform. Therefore, we extend the literature by examining how formal role relates to the relationship between expertise and advice-seeking in the context of urban middle school mathematics teachers' social networks. More specifically, we first explore how network centrality varies across formal role group (i.e., teacher, instructional coach, and principal/assistant principal), and second, we investigate how centrality relates to expertise within each formal role group. This study offers insight into the relationship between informal and formal aspects of school organizations, as it allows us to see how formal structure (role group) relates to informal interactions (advice-seeking behavior) in the context of accessing and perceiving expertise.

Literature Review & Theoretical Framing

In order to situate our examination of the relationships among formal role, expertise, and teachers' advice-seeking behaviors, we first synthesize findings from the literature on school social networks. We draw on theoretical perspectives commonly used in this literature to apply a lens of social capital theory to the analysis we present in this paper. In addition to examining research on social networks in schools, we summarize the literature on how different instructional leaders in schools can support teachers in improvement efforts. Finally, we explore the relationship between instructional leadership and school social networks.

Social Networks in Schools and Social Capital Theory

Teachers who seek advice on instruction are more likely to change their practice (Parise & Spillane, 2010), so understanding teachers' advice-seeking networks offers insight into the ways teacher collaboration can influence instructional practice, reform implementation, and ultimately student learning (Moolenaar, 2012). In this paper, we employ a lens of social capital theory to frame our analysis of advice-seeking and expertise. Social network researchers have often drawn upon social capital theory, which posits that people access resources through their social connections (Coleman, 1988, 1990; Bordieu, 1986; Portes, 1998; Lin, 2001). Coleman

(1988; 1990) laid out a framework for social capital with three components: trust, networks, and norms. With these components in place, the authors argue that social capital can be leveraged to disseminate information, build skills and capabilities, and increase efficiency. We follow previous researchers in taking the view that social capital can be used to access help (e.g. information or expertise) or to exert social pressure (e.g. pressure to conform) (Frank, et al., 2004). This perspective provides insight into the ways in which teachers' networks can be a source of information and of normative influence that have implications for practice (Moolenaar, 2012).

Teachers' social networks play an important role in the diffusion and implementation of educational reforms (Frank, Zhao, & Borman, 2004; Penuel, Sun, Frank, & Gallagher, 2012). Coburn and colleagues (2012) investigated the role of teachers' social networks in sustaining instructional reforms. When strong ties, high depth interactions, and access to expertise characterized the network, teachers were more likely to maintain instructional improvement efforts. Extending this work, Coburn, Mata, and Choi (2013) found that when a district adopted a new instructional initiative, teachers began to seek advice from colleagues with instructional expertise. Others have also shown that teachers who have already implemented reform are more likely to maintain and deepen implementation if they are situated in networks with expertise (Frank, Zhao, Penuel, Ellefson, & Porter, 2011). These studies indicate that access to expertise is important for implementing instructional innovations, and suggest that social pressures also play a key role in such endeavors.

One way to examine school social networks is to consider the centrality of members of the school community (Moolenaar, 2012), which indicates the prominence of individuals in the network. Centrality is often measured as the proportion of connections an actor has to others in the network to the total number of possible connections (e.g., Friedkin & Slater, 1994; Moolenaar, Daly, & Sleegers, 2010). When actors, and especially school leaders, are central in a school's network, they have the potential to access and distribute information, expertise, and resources (Balkundi & Kilduff, 2005; Krackhardt, 1996). "Centrality in an organization's informal communication network allows superiors to develop, maintain, and exercise their interpersonal influence" (Friedkin & Slater, 1994, p. 140). Centrality, which in this study indicates the extent to which individuals are sought after for advice on instructional issues, points toward those school members in a position to leverage social capital and thus, the potential for those actors to influence instruction.

Instructional Support and Role Groups

Numerous studies have identified multiple role groups (e.g., principals, coaches, and teachers) as having great potential to improve instruction (e.g., Biancarosa, Bryk, & Dexter, 2010; Gigante & Firestone, 2008), and researchers have argued for an examination of how multiple actors in schools, including both formally designated leaders and informal leaders, provide instructional leadership role in concert (e.g., Neumerski, 2013). "[T]he way we have organized our studies on principal, teacher leader, and coach instructional leadership into separate and distinct bodies of literature may constrain our ability to develop new types of knowledge" (Neumerski, 2013, p. 334). In this study, we consider all three of these groups and the ways in which expertise might influence their position as an instructional leader. Below, we examine the literature on how actors in each group exhibit instructional leadership.

Principals. Through interactions with teachers and management of the school, principals are central to the process of learning for instructional improvement (e.g., Bryk, et al., 2010;

Leithwood, Louis, Anderson, & Wahlstrom, 2004). Principals can actively support instruction by promoting and participating in teacher learning, evaluating teachers and the curriculum (Supovitz, Sirinides, & May, 2010; Robinson, Lloyd, & Rowe, 2008), systematically monitoring student progress (Tyack & Hansot, 1982), frequently observing classrooms (Bossert, Dwyer, Rowan & Lee, 1982), and providing expertise in curriculum development and teaching (Adams, 1999; Tyack & Hansot, 1982). Overall, principals considered to be high-quality instructional leaders were identified as strong, directive leaders who fostered school cultures focused on academic press and high expectations for all students (Hallinger, 2005; Heck et al., 1990; Marks & Printy, 2003; Rosenholtz, 1985). However, principals have multiple demands on their time, in that they typically have to devote time to tasks such as managing budgets, resources, schedules, and discipline issues (Grissom & Loeb, 2011). Further, we argue that it is unreasonable to expect principals to have content-specific expertise across content areas, particularly in middle and high school contexts.

Instructional Coaches. Given constraints on principals’ time and content-specific expertise, many districts and schools employ instructional coaches to provide support for teachers. Coaches can support teachers’ learning by engaging in activities such as co-planning, observing, and providing feedback (Gibbons, accepted). However, the effectiveness of instructional coaches is linked to the level of support from and alignment with principals (Carlisle & Berebitsky, 2010; Mangin, 2007). Instructional coaches tend to observe teachers more frequently when the principal has focused the coach’s role on supporting teachers in improving their instruction (Matsumura, Sartoris, Bickel, & Garnier, 2009).

Teachers. Like principals and instructional coaches, teachers have the potential to shape departmental climate around a shared vision of innovation or reform (de Lima, 2008), promote student achievement (Sammons, Hillman, & Mortimore, 1995), and support the growth of colleagues through modeling, mentorship, and other forms of professional development (Glover, Miller, Gambling, Gough, & Johnson, 1999; Harris, Jamieson, & Russ, 1995). In contrast to principals, teachers might serve as a formal instructional leader (e.g. as a department head or mentor), or they might serve as an informal instructional leader (e.g. without any formally designated leadership role).

As this brief review of the literature indicates, principals, instructional coaches, and teachers can all support teachers in instructional improvement, and in this paper, we seek to understand who teachers seek for instructional advice – which we interpret as one form of instructional leadership.

Instructional Leadership and Social Networks

Some prior research has investigated the role of instructional leaders in the context of school networks. Principal centrality has been linked to both the willingness of teachers to innovate (Moolenaar et al., 2010) and overall school performance (Friedkin & Slater, 1994). Moving beyond an exclusive focus on the principal as instructional leader, Spillane and Kim (2012) found that formal school leaders other than the principal, such as assistant principals, curriculum coordinators, and mentor teachers, occupied central positions in school social networks. These studies align with a significant body of work that suggests an important, though indirect, relationship between principals' instructional leadership and student learning (e.g. Supovitz et al., 2010; Leithwood et al., 2004; Hallinger & Heck, 1998). On the other hand, Sun, Frank, Penuel, and Kim (2013) found that principals, instructional coaches, and department chairs influenced general teaching practices (e.g. use of curriculum and assessments), whereas teachers without formal leadership roles influenced teachers' specific instructional practices (e.g. emphasis on basic skills). Similarly, Supovitz (2008) found that teachers who did not hold formal roles were nearly twice as influential as principals on teachers' reported changes to their instructional practices.

Taken together, the literature points to a need to better understand the phenomenon of advice-seeking in school networks, and the way in which that advice-seeking relates to formal role designation and access to expertise. While the centrality of formal leaders has been related to improved school outcomes, there is evidence that the advice teachers receive from one another has a different kind of influence. Paired with Coburn and colleagues' (2008, 2012) finding that access to expertise is an important factor for generating and sustaining instructional improvement, we argue there is a pressing need to better understand the relationships among teachers advice-seeking behavior, role group, and various forms of expertise within each role group.

Research Questions

For districts and schools attempting to improve instruction at scale, strong instructional leadership is a necessity (Cobb & Jackson, 2011). The literature highlights the importance of access to expertise, and the centrality of instructional leaders in schools can be a clear indicator of teachers' ability to access information and resources. This exploratory study serves to extend this work by looking at who teachers and other school members report turning to for instructional advice in the context of districts attempting to improve instruction at scale. We take into account the expertise and experience of principals, coaches, and teachers. Specifically, we pose the following research questions: In the context of middle school mathematics social networks, (1) What is the relationship between centrality and formal role group? and (2) What is the relationship between centrality and expertise within different role groups?

Data Sources & Methods

In order to examine the ways in which teachers' advice-seeking behaviors relate to formal role and expertise, we draw on a variety of data sources taken from a four-year study of a sample of schools and teachers in four large urban school districts. In particular, we rely on data from a network survey to document teachers' advice-seeking behaviors, and we draw on the broader data set to document formal role and measures of expertise within each role group. In this section, we provide an overview of the larger project from which the data are taken, with detailed descriptions of the sample, and how the data analyzed in this paper were collected. We then describe the variables used to explore our research questions, particularly those used as measures of expertise. Finally, we detail the methods employed to analyze the data.

Sample

The data for this study were collected as part of a larger, four-year study, which began in the 2007-2008 school year and was designed to address the question of what it takes to improve the quality of middle-grades mathematics instruction, and thus student learning, at scale. The project worked with four large, urban districts attempting to achieve a vision of high quality mathematics instruction that was broadly compatible with the National Council of Teachers of Mathematics' (2000) recommendations. Project leaders worked with district leaders to identify six to ten middle-grades schools that reflected the district's variation in student demographics, performance, and capacity for improvement; this resulted in the identification total of 30 schools across the four districts.

While the four districts were similar in some respects (e.g., they were all large, urban districts attempting to reform mathematics instruction in middle schools), they varied both geographically and demographically. Geographically, two of the districts were located in the Southwest region of the United States, one was located in the Southeast, and the fourth was located in the upper Midwest. The regional differences most likely had an influence on the demographic differences of the districts[2]. For instance, districts B and C both served a large number of Hispanic/Latino students (57.7% and 65.4% respectively). On the other hand, district D served mostly White (62.6%) and African American (37.0%) students. District A also had a smaller proportion of Hispanic/Latino students with the dominant racial groups also being White (48.7%) and African American (40.0%). Poverty was also prevalent in all four districts, with the percent of families living below the poverty line ranging from approximately 24% to 34%.

As in most urban contexts, schools in our districts faced the challenge of retaining teachers. Over the four years of the study, roughly 20% of our participants left their school; however, this number is most likely an underestimate as we were only able to track teachers that fully participated in the larger research project. We believe that teachers who were more likely to leave their schools were also less likely to volunteer for a research study. There was some variation by district as districts A and C had higher levels of retention (87.9% and 84.1% respectively over the four years) with districts B and D showing lower rates of retention (77.8% 67.8% respectively).

The four districts in our study also varied in their models of instructional coaching. District A had very few content-focused instructional coaches; in this district most content-specific instructional support for middle grades mathematics teachers came from a single district-based coach who coordinated professional development. Districts B and D had content-focused instructional coaches designated for each school. District D had a combination of district-based coaches (who served one or more schools) and school-based coaches (who served only one school), whereas district B had all school-based coaches, some of whom spent half their time teaching based on funding availability. District C had a limited number of district-based coaches that served Title I schools, and thus, not every school had a mathematics instructional coach in the building every day, or even at all.

In order to collect data on the social network in each school, all mathematics teachers, principals, assistant principals who oversee mathematics, and mathematics instructional coaches in each of these schools were sent a network survey that asked, “During this school year (including last summer), is there a person you have turned to for advice or information about teaching mathematics?” Respondents could nominate up to 10 people. The network survey also asked participants to provide demographic information including their gender, race/ethnicity, and years experience teaching mathematics. Surveys were emailed to each participant’s school email address in early February with reminders to respond sent weekly. After six weeks, those who had not completed the electronic survey were sent a paper copy of the survey to complete. In order to create as complete a network map as possible, anyone in a sampled schools who was nominated as a source of mathematics instructional advice was sent a survey to complete if they had not been included in the original survey distribution. (This method is often referred to in the network literature as “snowballing.”)

Additional data were collected from administrators, coaches, and a randomly selected sample of about 5 mainstream mathematics teachers per school. Those who participated in this additional portion of data collection were referred to as “full participants” – in contrast with those who only participated in the network survey. In this study, we employ the following data collected from full participants: 1) online survey of perceptions and beliefs, 2) assessment of mathematical knowledge for teaching (discussed further below), and 3) videotaped classroom instruction to assess instructional quality (also discussed further below). Principals and those assistant principals who played a role in overseeing mathematics instruction were surveyed but were not assessed on mathematical knowledge for teaching or instructional quality. Instructional coaches were surveyed and assessed for mathematical knowledge of teaching but were not videotaped to assess instructional quality.

The data for this paper are taken from Years 2, 3, and 4 of the project. The network instrument was developed using interview and pilot data in Year 1, so data from this initial year could not be included in these analyses. Across the three years, network survey responses were collected from 965 participants in 30 schools, which included 132 principal and assistant principal responses, 73 instructional coach responses, and 760 teacher responses. However, many participants participated during multiple years. Taking repeat participants into account, our sample included 79 unique principals and assistant principals, 50 unique coaches, and 407 unique teachers. The overall response rate for the network survey instrument for the three years was 73.6%.

Variables

Centrality. Our main variable of interest for this study is a person's centrality in their school's social network. Centrality enables us to identify the rate at which specific individuals are sought out for advice about mathematics instruction, and then relate this rate to each individual's formal role and measures of expertise. To calculate the centrality of each person within the school's social network, we took the ratio of the number of times that a person was nominated from within the school to the number of people in the school who could have nominated the person. The number of people who could have nominated an individual included all mathematics teachers, principals, assistant principals responsible for mathematics, and mathematics instructional coaches. Centrality was bounded between 0 (not nominated at all) to 1 (nominated by everybody in the mathematics network). The measure can be interpreted like a percentage; a centrality of 0.25 indicates that 25% of the people in the network nominated an individual. In some districts, instructional coaches worked out of the district central office and served multiple schools. As we sought to understand how often the coach was sought out in each school they worked, we calculated a separate centrality for a coach in each school they served at least one day a week. Therefore, the same coach could appear multiple times in our dataset. Descriptive information for this measure, as well as others, will be provided in the results section.

Expertise. Our analysis draws on four primary measures of expertise, which are each described in detail below: years of experience, instructional quality, mathematical knowledge for teaching (MKT), and gains in student achievement. These measures of expertise will allow us to examine the extent to which various forms of expertise relate to centrality – a contribution to the research on teachers' networks and advice-seeking behavior.

Years of Experience. For this study, we focused on measures of experience including how many years the participant had taught mathematics (for all participants), how many years the participant had worked as an instructional coach (for coaches), and how many years the participant had worked as a principal or assistant principal (for administrators).

Instructional quality. In order to assess the instructional quality of each fully participating teacher in our study, we video recorded one period of mainstream mathematics instruction for two consecutive days. These lessons were coded using the *Instructional Quality Assessment* (IQA; Crosson, Junker, Matsumura, & Resnick, 2003; Boston, 2012), which focuses on the cognitive demand of the lesson and the quality of the whole-class discussion. The developers have established reliability and validity of the rubrics (Boston & Wolf, 2006; Matsumura, Garnier, Slater, & Boston, 2008). Only fully participant teachers, who accounted for 50% of our teacher sample, were assessed on the IQA. Scores from the IQA rubrics for the two days were aggregated to create a single score, and the score was standardized to a mean of 0 and a standard deviation of 1 in analyses. Teachers without IQA scores were excluded from analyses that included the IQA measure.

Mathematical knowledge for teaching. We assessed all fully participating teachers' and instructional coaches' mathematical knowledge for teaching (MKT) by using a pencil-and-paper instrument developed by the *Learning Mathematics for Teaching* project (Hill, Schilling, & Ball, 2004). This assessment measures teachers' pedagogical content knowledge; this specialized content knowledge is distinct from general knowledge of mathematical content in that it focuses on content-specific knowledge needed for teaching (Ball, Thames, & Phelps, 2008). The instrument has a reliability index of .70 or above, and we use it to assess teachers' knowledge (Hill et al., 2004) with respect to two dimensions: number concepts and operations (NCOP) and patterns, functions and algebra (PFA). Raw scores were translated into Item Response Theory scale scores (provided by the developers), the determination of which was based on results from a pilot administration of the assessment to a national sample of approximately 640 practicing middle school teachers. In our sample, all instructional coaches and fully participating teachers completed the assessment; principals and assistant principals did not. Our analyses used a combined average of these two scale scores to form a single MKT score for each teacher and coach in each year. As with IQA, teachers and instructional coaches who did not complete the MKT assessment were excluded from analyses that included this measure.

Student achievement gains. Given the context of high-stakes testing pressures in schools in the era of No Child Left Behind, we included a variable derived from multi-level models of student achievement gain scores on the state-mandated mathematics assessments during the years of the study. For each teacher, we calculated a teacher-level random effect estimate that represents the teachers' average deviation from the school average gain score on the standardized test. This variable thus indicates how the students in each teacher's classes improved over the year in comparison to the rest of the school; teachers with higher scores on this measure saw greater gains in student performance than other teachers in the school. Given that our study focuses on centrality measured at the school level, examining student achievement gains relative to other teachers within a particular school is an appropriate choice. The measure was also standardized.

Other measures. In our analyses of coach centrality, we included additional measures that could help us understand coach centrality. Specifically, we examined the number of days per week the coach was assigned to the school (ranging from 0.5 days/week to 5 days/week) and teacher perceptions of coach expertise and role. The perception variables were included in a secondary analysis to understand how teachers' views of the expertise and role of the coach might be related to whether or not they choose to seek instructional advice from that coach. In this analysis, which will be discussed in greater depth below, we sought to explore how teachers' perceptions of expertise differed from our measures of expertise.

Perceptions were measured using five survey questions, all of which were measured on a 5-point Likert scale (strongly disagree to strongly agree).

1. My mathematics coach communicates a clear vision for mathematics instruction.

2. My mathematics coach possesses a thorough knowledge of the curriculum and related instructional materials.
3. My mathematics coach understands the challenges involved in using the curriculum effectively.
4. The purpose of the mathematics coach visiting my classroom is to directly assist me in improving my teaching.
5. The purpose of the mathematics coach visiting my classroom is to evaluate my teaching in terms of job performance.

The first three survey questions tap into a teacher's perceptions of the coach's expertise, so we used exploratory factor analysis to see if the three tapped into a single latent trait. All three items loaded on a single factor with loadings ranging from 0.840 to 0.894. Questions 4 and 5, on the other hand, asked teachers to characterize the purpose of a mathematics coach's classroom visits. We recoded each of these items into dichotomous measures that classified strongly agree and agree as one group and neutral, disagree, and strongly disagree into another. Therefore, question 4 indicates whether or not the teacher sees the purpose of the coach visits as supporting instructional improvement, and question 5 indicates whether or not the teacher sees the purpose as evaluative.

Analyses

Our analyses are organized around two central research questions that help us understand patterns of advice-seeking about mathematics instruction: (1) What is the relationship between centrality and formal role group? and (2) What is the relationship between centrality and expertise within role groups? We began our analytic work by generating descriptive summaries of study variables (centrality and measures of expertise) disaggregated by role group and district. District breakdowns allowed us to see differences that emerged in centrality and other measures that may relate to variance in district policies such as coaching models. We employ multilevel modeling for our analyses; specifically, each model is a three level model with level 1 containing individuals in a certain year, level 2 accounting for individuals that may appear in multiple years, and level 3 encompassing the 30 schools in our sample. Multilevel modeling is appropriate as our sample contains teachers, coaches, and administrators nested across years and within schools. By taking into account the ways teachers were nested across years and schools, we are able to better parse out the relationships among formal role, expertise, and centrality for participants within each school while accounting for dependencies within our sample. In each model, we explore centrality as our outcome. We also include district level fixed effects at the school level (level 3) to account for systematic variation between the 4 districts (e.g., differences in coaching models, time for teacher collaboration). In addition, differences in average centrality arose across the four districts, with district A participants having the highest average centrality at 0.18 and district B participants with the lowest average centrality of 0.10. In all models, district D is the reference group. The district context likely plays an important role in the social networks of these schools; however, four districts do not provide enough variation to model quantitatively. Given the limits in sample size, the district fixed effects represented the best option to account for the contextual differences in this analysis.

We address our first research question by considering the differences in centrality across three role groups: teachers, instructional coaches, and principals and assistant principals. To facilitate analyses, we grouped the principals and assistant principals together and refer to them as administrators throughout the rest of this paper for ease of communication. By regressing role group on centrality, this analysis helps us to understand who are the instructional leaders in these schools as determined by who teachers and other mathematics-related personnel report going to for advice on mathematics instruction. The model is as follows[3]:

Level 1 Model, Participant within Year Level

$$Centrality_{ijk} = \pi_{0jk} + \pi_{1jk} Coach_{ijk} + \pi_{2jk} Administrator_{ijk} + e_{ijk}$$

Level 2 Model, Participant across Years Level (1)

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

Level 3 Model, School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001} District\ A_k + \gamma_{002} District\ B_k + \gamma_{003} District\ C_k + \mu_{00k}$$

We address our second research question by examining the relationships between centrality and measures of expertise for each role group separately. Examining role groups separately allowed us to consider how expertise might relate to centrality differently by role group. Additionally, measures of expertise collected differed by role group, as described above. In examining teachers' centrality, we included the number of years experience teaching mathematics, instructional quality (IQA), mathematics knowledge for teaching (MKT), and the student achievement gain score.

Level 1 Model, Teacher within Year Level

$$Centrality_{ijk} = \pi_{0jk} + \pi_{1jk} MKT_{ijk} + \pi_{2jk} IQA_{ijk} + \pi_{3jk} Years\ Experience_{ijk}$$

$$+\pi_{1jk} Student\ Achievement_{ijk} + e_{ijk}$$

Level 2 Model, Teacher across Years Level (2)

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

Level 3 Model, School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001} District\ A_k + \gamma_{002} District\ B_k + \gamma_{003} District\ C_k + \mu_{00k}$$

For instructional coaches, measures of MKT, number of years of experience teaching mathematics, number of years coaching, and the number of days per week the coach was in the school were examined. These variables represented experience in multiple forms and expertise with mathematics; a student achievement measure was not included as coaches did not typically have a set of classrooms assigned only to them. The model is as follows:

Level 1 Model, Coach within Year Level

$$Centrality_{ijk} = \pi_{0jk} + \pi_{1jk} MKT_{ijk} + \pi_{2jk} Years\ Experience\ Coach_{ijk}$$

$$+\pi_{3jk} Years\ Experience\ Teaching_{ijk} + \pi_{4jk} Days\ In\ School_{ijk} + e_{ijk}$$

Level 2 Model, Coach across Years Level (3)

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

Level 3 Model, School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001} District\ A_k + \gamma_{002} District\ B_k + \gamma_{003} District\ C_k + \mu_{00k}$$

As will be described in detail in the results section, the coach analysis did not reveal any associations between coach centrality and measure of expertise even though coaches were the most central role group. To better understand what influenced whether or not teachers chose to seek advice from an instructional coach, we estimated a multilevel logistic model focusing on teacher perceptions of coach expertise and role.   This allowed us to determine, for instance, whether newer teachers or teachers with less expertise were more likely to turn to a coach for instructional advice. In this model, with equation below, we tested measures of teacher expertise and experience (MKT, IQA, and years of experience teaching mathematics) and included survey-based measures of teachers' perceptions of their mathematics instructional coach. This analysis helped us to understand how a teacher's own expertise and a teacher's perception of instructional coaches' expertise can influence their advice-seeking.

Level 1 Model, Teacher within Year Level

$$Nominate\ Coach_{ijk} = \pi_{0jk} + \pi_{1jk} MKT_{ijk} + \pi_{2jk} IQA_{ijk}$$

$$+\pi_{3jk} Years\ Experience\ Teaching_{ijk} + \pi_{4jk} Student\ Achievement_{ijk}$$

$$+\pi_{5jk} Perceive\ Expert_{ijk} + \pi_{6jk} Perceive\ Assist_{ijk}$$

$$+\pi_{7jk} Perceive\ Evaluative_{ijk} + e_{ijk}$$

Level 2 Model, Coach across Years Level (4)

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

Level 3 Model, School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001} District\ A_k + \gamma_{002} District\ B_k + \gamma_{003} District\ C_k + \mu_{00k}$$

Finally, the administrator model included years of experience teaching mathematics and years experience as an administrator. The administrators in our sample did not have any instruction videotaped or complete the assessment of mathematical knowledge; therefore, we were limited in the measures of expertise that could be included in this model. The model formula is as follows:

Level 1 Model, Administrator within Year Level

$$Centrality_{ijk} = \pi_{0jk} + \pi_{1jk} MKT_{ijk} + \pi_{2jk} Years\ Experience\ Admin_{ijk}$$

$$+\pi_{3jk} Years\ Experience\ Teaching_{ijk} + e_{ijk}$$

Level 2 Model, Administrator across Years Level (5)

$$\pi_{0jk} = \beta_{00k} + r_{0jk}$$

Level 3 Model, School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001} District\ A_k + \gamma_{002} District\ B_k + \gamma_{003} District\ C_k + \mu_{00k}$$

Results

The main findings in these schools were that: (1) centrality varies by role group: coaches were significantly more central than teachers who are significantly more central than administrators, (2) teachers with greater expertise were more central, (3) while coach expertise was not related to centrality, teachers were more likely to nominate a coach if they perceive the coach to have expertise and be evaluative, and (4) administrators were rarely nominated. In this section, we first discuss descriptive statistics for each role group. We then explore relationships observed between centrality and role group, considering teachers, administrators, or coaches. Finally, we examine what measures of expertise and experience are related to centrality for each of the role groups.

Descriptive Statistics by Role Group

Descriptive statistics, disaggregated by role group and district, are provided in Table 1. Mathematics teachers represented the largest role group in our sample with 760 survey responses across the four districts corresponding to 407 unique teachers. Teachers in district A had the highest average years of experience teaching mathematics with a mean of 14.11 years. On the other hand, the teachers in districts B and D tended to have much less experience (6.69 years and 8.13 years respectively). Teachers in district A also demonstrated the highest expertise as measured by the MKT and IQA, with standardized means of 0.51 and 0.33, respectively. District C had the least expert teachers as measured by both MKT (-0.43) and IQA (-0.56).

Insert Table 1 about here

Of 978 total network survey responses, 86 were from coaches. The four districts in our sample each employed a different coaching model; for example, district B coaches tended to be school based and worked part time as teachers while district D coaches all came from the district and served multiple schools. The instructional coaches in all four districts were meant to have expertise in mathematics pedagogy and content such that they could support teachers in the instructional improvement process. Most coaches in our sample spent at least 2 days per week coaching in their assigned school. The majority of coaches in our sample were in district D (39) with the smallest number found in district A (7). On average, the coaches in districts A and D had the highest levels of MKT; in both districts, the coach mean was more than half of a standard deviation above the nationally normed mean. The most experienced coaches were in district C with an average years experience teaching mathematics of 19.9 years and an average years coaching of 3.8 years. The other three districts all had coaches who had an average of 13-15 years experience teaching mathematics, and 2-3.5 years experience as an instructional coach.

Our dataset includes 132 survey responses from principals (84) and assistant principals (48), taken from 77 unique administrators. The administrators in district A had the highest mean years experience teaching mathematics at just under 7 years, whereas the average administrator in district D had less than 1.5 years experience teaching mathematics. However, the majority of administrators in our sample had no experience as a mathematics teacher. Experience as an administrator also varied with the most experienced administrators appearing in district A (9.22 years) and the least experienced in district D (4.84 years).

Centrality by Role Group

As described in the methods section, we calculated centrality by taking the number of nominations a person received and dividing that number by the total number of people in their school who could have nominated them. Mean centrality, disaggregated by district and role group, is shown in Table 1. Across our entire sample of 965 network survey responses, the mean centrality was 0.12 (SD = 0.16), which indicates that the average person in our sample received 12% of the possible nominations in their school. A small number of participants, just over 5%, had centrality values greater than 0.5 (meaning that at least half of the respondents in a school nominated that person as someone they turn to for advice about mathematics instruction).

Our first research question examines differences in mean centrality across the three role groups: teachers, coaches, and administrators. The results of the multilevel model (see equation set 1) can be found in Table 2. Administrators were significantly less central than teachers, and instructional coaches were significantly more central than teachers. On average, coach centrality tended to be 26% higher than that of teachers, and administrator centrality tended to be 7% lower than that of teachers.

Insert Table 2 about here

These results indicate significant differences in centrality among the three role groups. Administrator centrality is quite low, and in fact, nearly three quarters of principals and assistant principals had a centrality of zero. Of the 132 principal responses across the three years, 72.7% were never nominated as a source of advice on mathematics instruction. In comparison, 33.6% of teachers and only 1.9% of coaches had a centrality of zero. These numbers indicate that teachers in these schools did not commonly turn to middle school principals and assistant principals for advice on mathematics instruction. Although principals may be designated as instructional leaders, mathematics teachers and others in these schools were not seeking them out for instructional advice. Coaches, on the other hand, were nominated as an instructional resource in almost every school.

The findings indicate that formal role designation is certainly related to advice-seeking. To address our second research question, we explore the relationship between centrality and expertise for each role group. We first examine factors related to centrality of teachers, then instructional coaches, and finally, principals and assistant principals (i.e., administrators).

Teacher Centrality

We explored the data for relationships between teacher expertise and centrality through multilevel analysis that controlled for district (see equation set 2). We tested the following measures of expertise and experience: instructional quality (IQA), mathematical knowledge for teaching (MKT), years experience teaching mathematics, and student achievement gains for each teacher. Results of the model can be seen in Table 3.

Insert Table 3 about here

Three of the measures were significantly associated with a teacher's centrality while controlling for all other effects in the model: MKT, years experience teaching mathematics, and student achievement gains. Specifically, for teachers with a level of MKT one standard deviation higher than the norm, the centrality of that teacher tended to be about 2.3% higher than average. Furthermore, more years of experience teaching mathematics was associated with higher levels of centrality; an additional 10 years of experience in a mathematics classroom resulted, on average, in a centrality increase of 3%. Greater gains in student achievement were also related to higher levels of centrality with a one standard deviation increase in the measure associated with a

10.4% increase in centrality. A teacher's IQA score did not have a significant relationship to that teacher's centrality.

Coach Centrality

Next, we explored how measures of expertise and experience related to coach centrality. In this multilevel model, we tested years experience coaching, years experience as a mathematics teacher, and score on the MKT assessment (see equation set 3). In addition, we tested for the coach's availability by including a variable measuring how many days a week the coach spent in the school (values ranged from 0.5 days per week to 5 days per week).

Results of the analysis can be found in Table 4. Neither the coach's MKT nor the number of days the coach spent in the school was significantly related to centrality. However, two measures of experience were linked to the number of times a coach was nominated in a school. The years of experience as a coach had a marginally positive association ($p < .10$) where every additional year as a coach tended to result in a centrality increase of 2.3%. In addition, the coach's experience teaching mathematics was significantly related to coach centrality, but surprisingly, the relationship was negative with each additional year relating to a 0.8% decrease in centrality. A closer examination of the data revealed that the coaches in district C seemed to drive this negative relationship; district C coaches had the most years experience teaching mathematics and the lowest average centrality. Further, district C was also the only district in which, among coaches, years teaching was negatively correlated with MKT (r = -0.17).

Insert Table 4 about here

A Closer Look at Coach Centrality

While coach expertise was largely unrelated to greater levels of coach centrality, 98% of coaches received at least one nomination. As such, we wanted to understand what differentiated teachers who turned to a coach for advice from those others did not. More specifically, we were interested in the characteristics of teachers who turned to coaches for advice. Were these primarily new teachers, or teachers with low levels of expertise? Were there patterns in these teachers' perceptions of coaches?

To investigate, we conducted a multilevel logistic analysis of all teachers in our sample, using, as an outcome, a dichotomous variable of whether or not each teacher nominated a coach (see equation set 4). In this analysis, we had 542 teacher network survey responses across the three years, and of those, 43.36% nominated a coach. In this analysis, we first tested a number of characteristics of the teachers including years of experience teaching mathematics, IQA, MKT, and the student achievement gains of that teacher. None of these measures of teacher experience or expertise were significantly related to the odds of whether or not a teacher nominated a coach, indicating that newer teachers and teachers with lower levels of expertise were no more likely than others to turn to coaches for advice about mathematics instruction than their peers.

Insert Table 5 about here

Next, we tested teachers' perceptions of their coach's expertise and role. Results, as shown in Table 5, indicated that two aspects of teachers' perceptions were related to a significant increase in the likelihood that a teacher would nominate a coach. First, teachers who perceived the coach to have higher levels of expertise were more likely to nominate a coach. Specifically, teachers who had a one standard deviation higher level of perception that the coach has expertise tended to be more 3.25 times as likely to nominate a coach.

In addition, teachers who perceived coach visits to be evaluative were significantly more likely to nominate a coach as a source of advice about mathematics instruction. Holding other variables constant, the odds of a teacher nominating the coach increased by a factor of 2.45 for a one standard deviation increase in the teacher's perception that coach observations were for evaluation purposes. Interestingly, the perception of coach visits as being about teaching assistance did not significantly relate to the likelihood that a teacher would nominate a coach.

In summary, coaches were significantly more central than either teachers or administrators, and coach centrality was significantly related to years of experience, but not expertise as measured by MKT score. Also, if a teacher perceived the coach as having expertise or coach visits as evaluative, then the teacher was more likely to nominate a coach. We discuss these findings more deeply in the discussion section.

Administrator Centrality

While administrators were the least central of the role groups, we were still interested in exploring what factors might be related to principals' and assistant principals' roles as instructional leaders, as demonstrated by teachers nominating them as resources of advice on mathematics instruction (i.e., mathematics network centrality). Nearly 73% of administrators in our sample had a zero centrality, which means that none of the mathematics teachers in these administrator's schools reported seeking advice on mathematics instruction from them.

To explore factors related to administrator centrality, we conducted a multilevel model, which included the number of years of experience as a principal or assistant principal and the number of years of experience as a mathematics teacher (see equation set 5). As shown in Table 6, neither measure of experience was significantly associated with centrality. In summary, teachers rarely nominated administrators in our sample as sources of advice on mathematics instruction.

Insert Table 6 about here

Discussion

In this study, we sought to understand relationships among centrality, expertise, and formal role in urban middle schools attempting to reform mathematics instruction. Specifically, we posed the following research questions: (1) What is the relationship between centrality and formal role group? and (2) What is the relationship between centrality and expertise within different role groups? Our analyses provided interesting results for both questions. While our finding that coaches were more central than teachers is perhaps unsurprising, our finding that expertise was related to centrality for teachers, but not for coaches, certainly raises interesting questions and carries potential policy implications. Additionally, our finding that the principals in our study were rarely sought out for advice even when they had content-specific expertise provides an interesting contrast to findings in other settings (e.g. elementary school contexts) that merits discussion and has the potential to inform our understanding of how principals' work relates to formal and informal relations in school settings. We subsequently discuss implications for the relationship between centrality and role group, as well as relations between centrality and expertise within each role group.

Centrality and Role Group

Our finding that coaches are significantly more central than teachers, and that teachers are significantly more central than principals, has the potential to provide interesting insights when interpreted through the lens of social capital theory. As discussed in the literature review, we employ a lens of social capital in assuming that social networks can be used to access help (in the form of information and/or expertise) as well as to exert social pressure (such as the pressure to conform to certain pedagogical practices) (Frank, et al., 2004; Moolenaar, 2012). If we interpret interactions with middle grades mathematics instructional coaches to be those interactions that hold the greatest potential for both accessing information that is specifically about mathematics instruction (informational resources) and exerting or responding to social pressure (social resources), one might argue that these interactions have the greatest potential for to leverage social capital when compared to the other two role groups examined in our study. That teachers in our sample were more likely to nominate coaches if they perceive the coach as having expertise or an evaluative role supports this notion; the relation to perceptions of expertise suggest teachers are turning to coaches for informational resources, and the relation to perceptions of an evaluative role suggest teachers are turning to coaches in response to social pressure.

In the sampled districts, coaches often worked closely with both school level and district level leaders, and it is likely that at least some teachers saw the coaches as instruments of the administration. Therefore, teachers may have felt more pressure to go to coaches for instructional advice, which could at least partly explain the association between a teacher seeing a coach as evaluative and the teacher’s increased likelihood of nominating that coach (also in Table 5). Additionally, it is reasonable to argue that, as compared to members of other role groups, instructional coaches should have more time available to provide advice and help to teachers, given that working with teachers was a central component of the job expectation for the instructional coaches in our study. This may explain some the large mean centrality for coaches.

Interestingly, the number of days per week an individual spent working in a particular school as an instructional coach was not related to coach centrality. The relationship between the time coaches spend in schools and their position in the school advice network can inform how districts structure the role and responsibilities of the coach, and further research is needed to understand this relationship in more depth as our sample may not contain enough variance in coach models to present a full picture.

On the other hand, we suspect that while principals and assistant principals have the potential to exert a great deal of social influence, the fact that they were rarely sought out for advice about mathematics instruction is likely due to two primary factors. First, in cases where these administrators did not have a background in mathematics instruction, there may be little information to be gleaned specifically about mathematics instruction through this kind of advice-seeking. Second, even in cases where administrators did have a background in mathematics instruction, administrators were likely to have a limited amount of time to provide teachers with advice specific to teaching mathematics, as administrators are typically saddled with a variety of other responsibilities ranging including organization management (e.g., managing budgets and resources) and administrative management (e.g., managing schedules and discipline) (Grissom & Loeb, 2011). Our findings align with the work of Spillane and Kim (2012) who also found that leaders other than principals occupied central positions. Overall, our analysis indicates that formal role matters in school advice networks.

Teacher Centrality

Teachers have great potential to influence classroom instruction in classrooms other than their own – and thus can serve as an important source of instructional leadership (Lord & Miller, 2000; Mangin & Stoelinga, 2008). “For school reforms, one of the critical resources teachers can access is the expertise of their peers” (Penuel et al., 2010, p. 161). Our finding that teachers with greater expertise are more central suggests that, in some sense, advice-seeking among teachers may be self-optimizing, or those with more expertise and more experience are more often sought out for advice. Our findings about which measures of expertise related to teacher centrality (and which measures were unrelated) have the potential to offer insight into the kinds of expertise teachers value when seeking advice from their peers.

Our finding that years of mathematics teaching experience is significantly related to teacher centrality suggests that teachers seek advice from peers who may be more familiar with the curriculum or the school context. It is also plausible that teachers with more years of experience teaching have simply been around longer and thus cultivated a larger number of relationships that involve advice-seeking interactions. Our finding that mathematical knowledge for teaching is significantly related to teacher centrality suggests that teachers seek advice from peers who can offer insights about mathematical content and how students learn that content. Our finding that gains in student achievement is significantly related to teacher centrality suggests that teachers seek advice from peers who demonstrate effective teaching in the context of measurable student achievement outcomes that are consequential at the school and district level.

Given the current accountability climate, it is quite reasonable that having greater gains on standardized tests would be an indicator of expertise that teachers value in their peers. These findings are also consistent with Frank, Kim, and Belman’s (2010) argument that teachers seek to be more effective and leverage resources in their social networks toward this end. In addition, these findings challenge research that “suggests that teachers are often unaware of each other’s expertise and experience" (Moolenaar, 2012, p. 25). Instead, our findings suggest that teachers seem to be aware – even if not explicitly so – of multiple types of expertise including years of experience, mathematical knowledge for teaching, and gains in student achievement. In fact, the relationship between gains in student achievement and centrality of teachers was one of the stronger ones we observed. Future research is needed to better understand the extent to which teachers are consciously aware of the achievement gains of other teachers and how that influence instructional advice-seeking interactions..

Interestingly, our measure of instructional quality (IQA) was unrelated to teacher centrality. We find this particularly surprising given previous findings that the quality of teachers' instruction is influenced by the quality of those from whom they seek advice about mathematics instruction (Sun, Wilhelm, Larson, & Frank, 2014). This could be because teachers are not explicitly aware of the instructional quality of their peers, or because teachers do not have a shared view of what constitutes high quality instruction.

Our findings in this study also align with work currently being done by Wilhelm, Chen, Smith, and Frank (in press). Their analysis, which employs data from the same larger study as this paper, focuses on what factors are related to who teachers seek out for advice in the context of changing standards and external accountability systems. Like us, they find that teachers do seem to consider the relative expertise (e.g., differences in student achievement) of others when seeking advice. By employing a selection model procedure, they also take into account factors such as formal collaborative structures and homophily, which researchers have examined previously (e.g., Kochan & Teddlie, 2005; Coburn & Russell, 2008). They do not, however, look at a person's overall centrality, which can indicate influential people in the school social networks. Our findings, in concert with Wilhelm et al. (in press), indicate that teachers seem to be aware of the expertise of others in their school and will seek advice from those with expertise.

Coach Centrality

We were initially perplexed by our finding that, while coaches were more central than teachers, coach expertise was largely unrelated to coach centrality[4] whereas multiple measures of teacher expertise were related to teacher centrality. In order to better understand this finding, we explored what factors predicted the likelihood that a teacher would turn to a coach. This revealed that it was not teacher experience or expertise that predicted the likelihood of whether a teacher would turn to a coach, but rather that it was the teachers' *perceptions* of the coach's expertise and his or her role (whether the teacher perceived the coach to serve in an evaluative role) that predicted the likelihood that a teacher would seek advice from a mathematics instructional coach.

There are a number of possible explanations for why coach centrality might *not* be related to our measures of expertise. As discussed above, the ideas of informational and social resources in social capital theory may explain some of these findings. Teachers may see coaches as strong informational resources, and in addition, school and district leaders may exert normative pressure on teachers to seek assistance from instructional coaches. Furthermore, the coach may be the most available person to offer advice as, in many instances, the coach's primary responsibility was supporting teacher instructional improvement.

Another possibility is that elevating someone's social status by designating him or her as a coach may interfere with teachers' perceptions of expertise. Role designation may alter teachers' perceptions of the normative environment; for example, where previously a fellow teacher was simply a colleague, now that person may be seen as an arm of the administration. In addition, there may be aspects of a coach's work that may relate to his or her centrality but that wouldn't be considered a form of expertise; for instance, the coaching literature suggests that factors such as trust, familiarity with curricular materials, and 'coaching ability' (for which we lacked a measure) are important conditions to consider with regard to collaboration between a teacher and an instructional coach (Gibbons, Wilhelm, & Cobb, 2011). This suggests that there are likely forms of coach expertise that our study fails to capture.

As in prior studies that explored how the role and expertise of coaches can influence depth of interactions with teachers (e.g., Coburn & Russell, 2008), our findings also have the potential to inform ways in which districts structure coach responsibilities, especially given our finding that teachers more often nominated coaches if they perceived coach observations to have an evaluation component. This result may be an indication of a self-preservation effect in schools; if teachers feel that the coach's evaluation of them is important, they may be more likely to seek out the coach for advice in order to figure out what they need to do to receive better evaluations. Another explanation could reside in district policy regarding the role of the coach; coaches may be assigned to work with certain, struggling teachers, which teachers could perceive as a component of evaluation. As mentioned above, districts in our sample did vary in their coach models (e.g., some coaches were teacher-coach hybrids, some coaches served only one school, some coaches served multiple schools). Interestingly, part-time coaches (e.g., district B coaches worked as half time coach, half time teacher) tended to be as central as full-time coaches. Other aspects of the districts could account for the lack of difference between part-time and full-time coaches. These role differences in coaching models employed by the districts and schools may contribute to teachers' willingness to seek instructional advice; however our data did not allow us to adequately explore these potential relationships. Future research will hopefully explore the influence of coaching models and the potential for different models to explain not just why perceiving coach observations as evaluative is associated with higher centrality, but also how different models (e.g., coach serves only one school vs. serving multiple schools) relate to teachers' advice-seeking.

The literature suggests that coaches can be an important support for teachers working to implement pedagogical reforms (Showers & Joyce, 1996; Neufeld & Roper, 2003). Given the documented importance of coach expertise for supporting instructional improvement (e.g. Coburn et al., 2012; Cobb & Jackson, 2011), we argue that schools and districts should carefully consider hiring criteria and decisions for instructional coaches, with a particular emphasis on pedagogical content knowledge and instructional vision. Coburn and Russell (2008) found that when hiring decisions about instructional coaches were made at the district level, coaches had uniformly higher levels of expertise as well as greater success in achieving instructional reforms in their schools. Anecdotally, we have witnessed instances when school level administrators selected their instructional coaches in ways that aimed to remove ineffective teachers from the classroom. Our findings suggest that this can be particularly problematic, as coaches in our schools tended to occupy a central position regardless of their expertise. As such, we argue that district leaders and policymakers should carefully consider the criteria used to hire instructional coaches.

Administrator Centrality

The fact that administrators were sought out for advice at such low levels across the board is noteworthy. For a number of years, policymakers and researchers have focused on the role of the principal as the primary instructional leader of the school, and the district leaders from our sample were no different. Principals in all four districts studied were expected to act as instructional leaders by working directly with teachers to improve instruction, and most of the districts provided extensive professional development to help principals in this role. In many schools, assistant principals with mathematics teaching expertise were hired specifically for the purpose of supporting instructional improvement in mathematics. However, our analyses indicate that teachers rarely nominated administrators as a resource for advice on instruction. These findings align with the work of Spillane and Kim (2012), who also found that principals were rarely a central actor in school networks. Devos, Tuytens, and Hulpia (2014) offer insight into the role principals do play, finding that in secondary schools, principal leadership had an indirect effect on teachers' organizational commitment as the influence of principal leadership was mediated by assistant principals and teacher leadership. Overall, middle school mathematics teachers in our sample rarely sought advice from principals and assistant principals with regard to their mathematics instruction.

The results of our analyses are interesting given the prior findings of Friedkin and Slater (1994) who identified a significant relationship between principal centrality and school performance. As so few of the administrators in our sample had a non-zero centrality, we wonder if the divergence in findings may emerge from the context of our study in comparison to theirs. One difference between our study and theirs is the level of schooling; their work was situated in elementary schools, while ours is in middle schools. It is possible that the content specialization of middle schools, much like high schools, alters the way teachers and administrators interact around instruction. Research has shown that the role of the principal is different in elementary schools as compared to the role in secondary schools (Firestone & Herriott, 1982). Elementary school principals tend to be more involved in planning and supervising instruction; secondary principals delegate leadership responsibilities and tend to exert influence indirectly and symbolically (Caruso, 1989; Johnson & Holdaway, 1990). However, the differences in findings could also be attributable to the age of Friedkin and Slater's work and the subsequent changes in schools and districts over the past 20 years. For example, the implementation of No Child Left Behind could have altered teachers' advice-seeking patterns, as teachers need new knowledge to contend with the new policy environment. More recent research (e.g., Spillane & Kim, 2012; Supovitz, 2008, Sun, Frank, Penuel, & Kim, 2013) on principal centrality tends to support our findings that the principal may be less likely to play a central role in the school. However, this work is highly context dependent, and further research is needed to compare the network positions of principals and assistant principals across school levels and the corresponding relationship of administrator centrality to school performance.

These findings are important in how we think about the role of the principal in leading instruction in the school. School leaders are "the catalyst for local change" (Bryk et al., 2010, p. 126), but what is their role when districts are attempting to change instruction at scale? Researchers have routinely discussed the role of the principal as actively supporting instruction (Supovitz et al., 2010), and policymakers have codified this role in setting principal standards. However, researchers have begun to look differently at the role of the principal. Grissom and Loeb (2011) showed that organizational management skills were the most consistent predictors of student achievement across 42 principal leadership tasks; instructional management activities did not consistently correlate with schools that made the most gains. Given these findings and our results, principals and district leaders may want to consider multiple ways in which school leaders can positively influence instruction in addition to direct instructional leadership.

Limitations

This study has some limitations worth noting. First, we cannot conclude any causal relationships among our measures. Expertise may cause centrality, but it is possible that centrality could cause expertise (e.g. those who are frequently involved in conversations about instructional matters are likely to learn from them). Future research is needed to explore the potentially symbiotic relationship between centrality and expertise. Second, our sample was limited to middle schools in four large urban districts; therefore, our findings are not necessarily generalizable to other grade levels and district contexts. The urban district context of our study most likely contributed to our findings, and future research will hopefully be able to look at how different district contexts influence the relationships among formal role, expertise, and centrality. For instance, in rural schools where there is only one teacher per grade level or for many grade levels in mathematics, teacher networks are likely to look quite different; it may be that it is important for teachers in these settings to gain access to virtual networks for content-specific instructional advice-seeking in order to support their professional growth. Third, we were unable to obtain a full complement of expertise measures within and across role groups. For example, monetary and labor costs prevented us from videotaping every mathematics teacher across the 30 schools. By randomly ordering the selection of teachers within schools, we hoped to obtain a representative sample of teachers but bias could exist. Finally, other measures of expertise may shed light on centrality. While our findings provide many interesting relationships, different measures of knowledge and instructional quality could help us to further understand why teachers choose to seek advice from certain people and not others.

Conclusion

To improve instruction at scale, schools and districts need to provide substantial support to teachers, and schools' school social networks are one mechanism through which instructional innovations are interpreted and propagated (Frank, Zhao, & Borman, 2004; Penuel, Sun, Frank, & Gallagher, 2012). Our findings support the idea that teachers are accessing information from those in the network with expertise and experience. The finding that teachers seek out other teachers who have expertise suggests that advice-seeking among teachers is in some ways self optimizing. The strength of the relationship between student achievement gains and centrality suggests that teachers are explicitly aware of which of their peers are effective at getting their students to make gains on the tests that matter for accountability purposes, and that teachers' advice-seeking behaviors are accordingly shaped by accountability pressures. This claim is strengthened by the relationship between teachers' perceptions of coach observations as evaluative and the likelihood that a teacher will turn to a coach for instructional advice. Taken together, this suggests that teachers' advice-seeking is shaped both by their efforts to access expertise and in response to accountability pressures. This creates a cautionary tale against the misalignment of formal role and expertise. Our findings suggest that those in a social network whose social status is elevated to the formal role of coach are more sought out for advice, particularly if they are perceived to have evaluative power. This can inform what administrators can expect of teachers' informal advice-seeking as well as how advice-seeking patterns are likely to shift if a teacher is made a coach.

In this study, we have not linked teacher advice-seeking to formalized structures for teacher collaboration (e.g. the provision of time and/or expected activity structures for school-based teacher collaboration), but anecdotally, teachers' networks do seem have more connections when this provision is made. Additionally, Coburn et al. (2012) have found that teachers' interactions do not necessarily have greater depth as a mere result of additional meeting time, but rather that the depth of interactions in teachers' interactions is related to the nature of conversations that take place in teachers' collaborative meetings. As such, while we have not examined the relationship between teacher networks and formal structure for teacher collaboration, the literature would suggest that these connections are important and merit additional examination.

Given these findings, we call for policymakers and district leaders to carefully consider how best to empower instructional leaders in the school other than the principal. If coaches are going to be sought for advice by most teachers, then we argue it is important that district leaders ensure that only the most expert people fill those roles. In addition, the lack of centrality for principals and assistant principals does not mean that administrators do not have an important role in the instructional improvement process. They most likely serve in more facilitative, indirect roles (e.g., Louis, Leithwood, Wahlstrom, & Anderson, 2010), which is important for policymakers and practitioners to understand when making decisions about how principals spend their time. Finally, it is valuable for school and district leaders to attend to the roles of formal and informal teacher leaders. Our analyses indicate that teachers seek out more expert and experienced colleagues for advice on mathematics instruction. It behooves policymakers and practitioners to foster desired connections, as strong network ties play an important role in the reform adoption process (e.g., Coburn et al., 2012; Finnigan, Daly, & Che, 2013). These findings inform ways in which reform efforts at scale can be supported, and there is benefit for policymakers looking to improve instruction to consider how best to facilitate the growth of productive networks.

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Table 1

Descriptive Values for Measures of Expertise and Experience by Role and District

District	Role	Centrality	Years Exp. Math	MKT	IQA	Years Exp. Coach	Coach Days	Years Exp. Admin
A	Teacher (*n* = 140)	0.21	14.11	0.51	0.33			
	Coach (*n* = 7)	0.40	13.33	0.81		2.00	4.86	
	Admin (*n* = 41)	0.06	6.91					9.22
B	Teacher (*n* = 236)	0.08	6.69	-0.13	0.09			
	Coach (*n* = 21)	0.41	15.14	-0.11		2.81	5.00	
	Admin (*n* = 34)	0.05	2.83					5.26
C	Teacher (*n* = 212)	0.10	10.37	-0.43	-0.56			
	Coach (*n* = 13)	0.31	19.91	-0.07		3.80	3.08	
	Admin (*n* = 23)	0.03	3.32					7.24
D	Teacher (*n* = 172)	0.10	8.13	-0.16	0.10			
	Coach (*n* = 32)	0.41	13.93	0.53		3.50	3.10	
	Admin (*n* = 34)	0.02	1.48					4.84

Note. All *n* values indicate the maximum possible responses for that role in that district. Actual *n* will vary for the specific variable.

Table 2

Multilevel Analysis of Role on Centrality

	Coefficient		Standard Error
Constant	0.098	***	0.012
Coach[a]	0.263	***	0.017
Administrator[a]	-0.074	***	0.014
District A[b]	0.080	***	0.017
District B[b]	-0.008		0.016
District C[b]	-0.009		0.016

Note. n = 965 responses, 533 individuals, 30 schools.
~ $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$
[a]Reference group is Teacher.
[b]Reference group is District D.

Table 3

Multilevel Analysis of Expertise and Experience on Teacher Centrality

	Coefficient		Standard Error
Constant	0.102	***	0.024
MKT	0.023	*	0.008
IQA	0.009		0.008
Years Experience Teaching Math	0.003	*	0.001
Student Achievement Gains	0.104	*	0.051
District A[a]	0.052		0.034
District B[a]	-0.024		0.032
District C[a]	0.012		0.034

Note. n = 333 responses, 174 teachers, 30 schools.
~ $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$
[a]Reference group is District D.

Table 4

Multilevel Analysis of Expertise and Experience on Coach Centrality

	Coefficient		Standard Error
Constant	0.438	***	0.099
MKT	0.010		0.037
Years Experience as Coach	0.023	~	0.012
Years Experience Teaching Math	-0.008	**	0.003
Days in School	0.002		0.020
District A[a]	0.189		0.197
District B[a]	0.017		0.071
District C[a]	-0.020		0.077

Note. $n = 59$ responses, 41 coaches, 19 schools.
~ $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$
[a]Reference group is District D.

Table 5

Multilevel Logistic Analysis of Whether or Not Teachers Nominate a Coach

	Odds Ratio		Standard Error
Constant	0.881		0.448
MKT	1.376		0.376
IQA	1.020		0.193
Years Experience Teaching Math	1.002		0.021
Student Achievement Gains	2.050		2.659
Teacher Perceive Coach Expert	3.247	***	1.037
Teacher Perceive Coach Assist	1.103		0.557
Teacher Perceive Coach Evaluative	2.447	*	1.055
District A[a]	0.617		0.495
District B[a]	0.547		0.231
District C[a]	0.544		0.291

Note. n = 205 responses, 130 teachers, 24 schools.
~ $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$
[a]Reference group is District D.

Table 6

Multilevel Analysis of Expertise and Experience on Administrator Centrality

	Coefficient	Standard Error
Constant	0.017	0.021
Years Experience as Administrator	-0.002	0.002
Years Experience Teaching Math	0.001	0.002
District A[a]	0.009	0.027
District B[a]	0.038	0.026
District C[a]	0.027	0.027

Note. n = 105 responses, 64 administrators, 30 schools.
~ $p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$
[a]Reference group is District D.

Endnotes:

1. The selection of the districts in our study was driven by three criteria: 1) The district has identified middle-school mathematics as a priority area and has developed an improvement plan; 2) the district has adopted a middle-school mathematics curriculum that affords teachers opportunities to foster students' conceptual understanding of central mathematical ideas (e.g., Connected Mathematics); and 3) the district's improvement plan includes ongoing teacher professional development that is school- based, is organized around the instructional materials teachers are using, and focuses on both mathematical content and student learning.

2. Racial and socioeconomic demographic numbers in this paragraph were obtained from the Education Demographic and Geographic Estimates database from the National Center for Education Statistics (http://nces.ed.gov/programs/edge/).

3. In the model equations, we format equations based on those used by Raudenbush and Bryk (2002). For example, pis, betas, and gammas all represent regression coefficients (slopes or intercepts) at their respective levels.

4. The exception being the marginally significant negative association between coaches' centrality and their years experience teaching mathematics, which we believe to be driven by the high experience and low centrality of coaches in district C.