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Selecting Expertise in Context: Middle School Mathematics Teachers' Selection of New Sources of Instructional Advice

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Given prior research indicating that teachers can learn through their social network interactions with colleagues, it is important to understand more about the choices teachers make about whom to go to for advice. In this study, we investigated the degree to which middle school mathematics teachers change from whom they seek advice when confronting new teaching

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standards and external accountability pressures (e.g., standardized tests). We found that colleagues' ability to improve student achievement was significantly related to advice seeking. In particular, teachers were more likely to seek new advice from colleagues who were better at improving student achievement. In contrast, relative differences in other types of expertise were not associated with advice seeking.

KEYWORDS: expertise, teacher social networks, accountability, selection modeling

Over the past several decades, there has been increasing emphasis on test-based accountability in schools in the United States. The signing of the No Child Left Behind Act (NCLB; 2002) solidified this emphasis. NCLB required that all students achieve at the proficient level or higher (defined by each state) in mathematics and English language arts on state standardized tests by 2014, with schools being held accountable for all students making adequate yearly progress (AYP). Ultimately, if a school did not meet AYP for four consecutive years, it was identified for corrective action (e.g., replacing ineffective school staff or implementing a new curriculum) (Cowan, 2003). The emphasis on students' achievement on state standardized tests in NCLB has led some principals to emphasize increasing test scores as their primary goal (O'Day, 2004). In contrast, some principals have encouraged teachers to focus on high-quality instruction, suggesting that test scores will improve with improvement in instructional practices (Elmore, 2004, 2006).

Recently, a number of disciplines have put forth standards for student learning (e.g., Common Core State Standards, Next Generation Science Standards). In mathematics, new standards for students' mathematical learning have been put in place over the past two decades (e.g., see National Council of Teachers of Mathematics [NCTM], 1989, 2000; National Governors Association for Best Practices & Council of Chief State School Officers, 2010). While the new standards reflect more ambitious goals for students' mathematical learning, they also imply a fundamental restructuring of practice in mathematics teachers' classrooms—a new vision for high-quality mathematics instruction. In particular, teachers need to engage students in more challenging tasks and facilitate opportunities for rich mathematical discussions of those tasks (Fraivillig, Murphy, & Fuson, 1999; Stein, Engle, Smith, & Hughes, 2008; Stein, Grover, & Henningsen, 1996).

Many of these instructional expectations depart from what teachers learned in their preservice programs or experienced themselves in school (e.g., Lortie, 1975). Therefore, it is challenging for teachers to develop the types of instructional practices described in the standards documents and requires considerable learning (e.g., Ball & Cohen, 1999; Elmore, Peterson, & McCarthey, 1996; Lambdin & Preston, 1995; Thompson & Zeuli, 1999).

While most teachers participate in professional development (PD) annually, research on the link between PD participation and improvement in teachers' instructional practices reveals mixed outcomes (Goldsmith, Doerr, & Lewis, 2014). However, the literature on professional learning (e.g., see Bruner, 1996; Lave & Wenger, 1991) suggests that interactions with colleagues can serve as productive opportunities for learning as teachers work to develop their instructional practices. Further, there is evidence that interactions with colleagues can support teachers' development and adoption of reforms (e.g., Daly, Moolenaar, Bolivar, & Burke, 2010; Frank, Zhao, & Borman, 2004; Penuel, Riel, Krause, & Frank, 2009; Penuel, Sun, Frank, & Gallagher, 2012).

Increased accountability for students' test scores and more rigorous standards for mathematics teaching pose multiple and potentially competing demands on teachers (e.g., experimenting with new instructional methods while being expected to increase test scores). Correspondingly, teachers may turn to their local (intra-school) networks to learn how to adapt their practices in response to new expectations for teaching and learning (Penuel, Frank, Sun, Kim, & Singleton, 2013). Teachers' advice-seeking networks affect not only the specific teaching outcomes but form the backbone of social capital that will be available to teachers to modify and innovate future practices (e.g., Frank et al., 2004). In this study, we investigate the degree to which teachers change from whom they seek advice when confronting external accountability pressures (e.g., standardized tests) and new standards. While expertise is central to understanding teachers' development through interactions with colleagues (Kruse & Louis, 1995), the role of expertise in teachers' advice-seeking behavior has been largely unexplored. The main contribution of this article is an exploration of the role of different forms of expertise in teachers' advice seeking in the context of competing expectations (e.g., accountability and standards).

Literature Review

In our investigation of changes in mathematics teachers' advice seeking in the context of competing accountability versus improvement initiatives, we draw on four different bodies of literature to guide our work. These bodies are professional learning, teacher expertise, social network selection modeling, and accountability. We do not rely on a single theoretical framework but instead identify elements in all four areas that work together to frame teachers' advice seeking in the context of competing accountability and improvement initiatives.

Professional Learning

Studies of professional learning suggest that co-participation in activities that approximate the targeted practices with relative experts is critical for the learning of complex practices (Bruner, 1996; Lave & Wenger, 1991). For example, applied to teaching, joint lesson planning with another teacher who is proficient at lesson planning has the potential to improve the less proficient teacher's lesson planning skills and, relatedly, instructional practice. Specifically, teachers can draw on interactions with experts (e.g., colleagues or coaches) to increase their implementation of new practices (Frank et al., 2004; Penuel et al., 2010; Sun, Frank, Penuel, & Kim, 2013; Sun, Wilhelm, Larson, & Frank, 2014). More generally, collaboration with colleagues has been shown to support teacher learning and influence student achievement (e.g., Bryk, Sebring, Allensworth, Luppesco, & Easton, 2010; Louis, Marks, & Kruse, 1996; McLaughlin & Talbert, 2006).

While the professional learning literature suggests that advice-seeking interactions have a greater potential to influence learning when they are with a more accomplished colleague, it is less clear how the relative accomplishment of colleagues influences teachers' decisions about with whom to interact. For example, prior research suggests teachers seek interactions based on affinity with others, such as same race, gender, or similarity of grade level (see the review in Frank, Lo, & Sun, 2014). In addition, Spillane, Kim, and Frank (2012) found that teachers also sought advice from colleagues who had participated in subject-relevant professional development. Coupled with several recent studies that used interviews with teachers to highlight the role of expertise in teachers' advice seeking (Coburn, Choi, & Mata, 2010; Spillane, Hopkins, & Sweet, 2015), it seems that teachers may deliberately seek specific expertise, beyond just shared context or affinity, in their interactions, especially when they want to improve their teaching practice (Frank, Kim, & Belman, 2010).

Spillane and colleagues (2015) related their findings to the notion of transactive memory (Wegner, 1987), with a focus on the idea that formal positions (e.g., instructional coach) signal which colleagues hold particular expertise. Here we consider the degree to which teachers are strategic in seeking interactions with other teachers who hold specific expertise, above and beyond that indicated by formal position, that could help them respond to current external demands (e.g., teaching to standards or responding to accountability pressures). We investigate whether they seek advice from particular colleagues because of their expertise, which would indicate that teachers are aware of which teachers hold specific forms of expertise.

Teacher Expertise

In order to understand how expertise factors into teachers' decisions about from whom to seek advice, it is important to consider both the forms of expertise that are central to teaching and the expertise that is most available and observable to colleagues. First, we take the perspective that teachers' knowledge is situated, meaning that knowledge for teaching (e.g., a teacher's understanding of an instructional technique) cannot be separated from teaching knowledge in use (e.g., the teacher's use of the technique in the classroom) (Brown, Collins, & Duguid, 1989). Thus, when attempting to measure a component of knowledge for teaching (or expertise), it is impossible to represent it in its true form as we only see how the knowledge was put to use in the classroom. By focusing on measures designed to be proximal to the practices of teaching, however, it is more likely that those measures are near approximations of the expertise itself. In our study of mathematics teachers, we take mathematical knowledge for teaching (MKT), a teacher's description of their instructional vision, and observed instructional practice as proxies for central aspects of teaching expertise. MKT is mathematics content knowledge specific to the work of teaching (e.g., common misunderstanding of fractions, multiple ways that students can solve the same problem and get a mathematically correct answer) and goes beyond content knowledge that others fluent in mathematics know (Hill, 2007). A teacher's instructional vision is the image of classroom practice that that teacher is aiming for (Munter, 2014). For example, a teacher might value the implementation of challenging tasks in the classroom, and this would be a component of his vision, even if he has not mastered their implementation yet. Finally, a measure of observed instructional practice attempts to objectively describe a teacher's actual teaching practice in the context of a particular set of instructional foci. In our study, we take the instructional foci to be the use of mathematically challenging tasks and the quality of related whole-class discussions because those were the foci of instructional reforms in the participating districts.

Other measures of expertise that are used in research do not always reveal as much about what a teacher knows or does, focusing more on what a teacher has experienced or accomplished. For these measures, what a teacher knows or does is typically implicit. Prime examples of these types of measures are the number of years of experience teaching and students' performance on standardized tests. These measures do not reveal specifics of what a teacher does in the classroom, but colleagues may consider them as indicators of expertise. In addition, these measures are more easily observable or obtainable than the more situated measures of teacher expertise. Teachers generally know about their colleagues' experience teaching because in a school it is typically discussed who are the veteran and who are the novice teachers. There is often, then, an implicit assumption that the veterans are more expert than are novices. In schools where teachers and administrators are talking about how students are doing on assessments and making it clear that demonstrated results are valued, it is likely that student performance will be also considered an indicator of a teacher's expertise. While the proxy measures of central aspects of teaching expertise (math knowledge for teaching, vision of instruction, quality of observed practice) are potentially less visible to teachers than the implicit measures, some ways that they could become more visible are through conversations with other teachers about instruction or about mathematics problems or conversations with the principal who recommends particular teachers as sources of expertise.

Social Network Selection Modeling

When trying to understand teachers' learning opportunities, analyzing a school's social networks is a means of investigating patterns in teachers' advice-seeking interactions with colleagues. Given prior research indicating that teachers can learn through their interactions with colleagues, it is important to understand more about the choices teachers make about whom to go to for advice. Network selection modeling focuses on individual teachers' decisions to seek advice from particular colleagues, including the knowledge and background of both the seeker and the colleague sought (Frank, Kim, & Belman, 2010). For example, these models allow one to test whether less expert teachers are more likely to seek advice from more expert colleagues to become more effective.

Much of the current research on teachers' social networks draws on the sociological literature about homophily (i.e., like characteristics; see McPherson, Smith-Lovin, & Cook, 2001) such as matching on gender, age, experience, ethnicity, grade level, subject matter, and physical proximity (Moolenaar, 2012). We found only five studies that have used selection models to examine the formation of teachers' social networks, all examining networks in elementary schools. Results from these studies are consistent with the more general findings pertaining to homophily: Teachers tend to seek advice from colleagues who are the same gender (Frank & Zhao, 2005; Moolenaar, Daly, Sleegers, & Karsten, 2014; Spillane et al., 2012), the same race (Spillane et al., 2012), and teach the same grade level (Frank & Zhao, 2005; Moolenaar et al., 2014; Penuel et al., 2010; Spillane et al., 2012, 2015).

In those studies, some individual characteristics were also related to advice seeking: Teachers are more likely to seek advice from more experienced colleagues (Moolenaar et al., 2014; Spillane et al., 2012, 2015) and more likely to seek advice from those holding a leadership position (Moolenaar et al., 2014; Spillane et al., 2012, 2015). In addition, Penuel and colleagues (2010) found that participating in meetings together increased the chances that teachers sought advice from one another. Complementing this finding, Spillane and colleagues (2012) found that teachers sought advice from those who had attended relatively more PD. They suggested that teachers might view PD attendance as an indication of expertise and seek out teachers who they perceive as more expert. In a subsequent study, Spillane et al. (2015) found that teachers sought advice from colleagues in formal positions (e.g., instructional coaches), and when asked about this in interviews, teachers suggested that they saw formal positions as indicators of expertise. Further, these authors suggest that in the two districts they studied, holding a subject-specific leadership position may have been a better indicator of expertise than either experience or PD.

In this analysis, we extend these findings with selection models focused on the expertise of colleagues and the advice seekers themselves. However, we control for a number of the previously investigated factors including personal characteristics (e.g., gender, race), aspects of homophily (e.g., same race, same gender, same grade level), and aspects of the context (e.g., shared meeting time).

Accountability

Prior research suggests that the increase in high-stakes testing over the past 15 years, most recently related to NCLB, has influenced teachers' work in schools. There is some evidence that high-stakes testing has influenced teachers' instructional practices, such as narrowing the content taught to what is tested and incorporating more test preparation into classroom instruction (Herman, 2004). These types of changes are relatively easy to make and would not be considered the kind of change in teachers' instructional practice called for in the NCTM standards (Supovitz, 2009). We seek to add to this literature by examining how school-level emphasis on high-stakes testing influences teachers' advice-seeking behavior. Accountability scholars acknowledge the important role that interactions between colleagues play in the effect of accountability policies on organizational change. In particular, O'Day (2004) suggested that "successful school improvement is dependent on two related factors—*interaction* (through which actors obtain information) and *interpretation* (through which they make meaning of that information and are able to act on it)" (p. 20). Some accountability scholars take the perspective that test-based accountability systems provide information, and therefore, we might expect an emphasis on testing to help reveal teachers who are more successful at improving test scores (Supovitz, 2009). If other teachers are then motivated to improve test scores, we would expect them to seek advice from colleagues who demonstrate the ability to improve test scores. We hypothesize that the institutions of accountability and instructional standards have different effects on teachers' networks. The institution of accountability would push teachers to seek others associated with improvements in students' test scores while the institution of standards may push teachers to seek others who engage in inquiry-based mathematics instruction.

Summary

Literature pertaining to professional learning, teacher expertise, selection modeling, and accountability helps us frame our expectations regarding how relative expertise influences teachers' decisions about advice seeking. We consider the individuals and their decisions in light of the contexts in which they work as they seek advice about teaching mathematics, which ultimately influences their learning opportunities with colleagues. While certain advice-seeking patterns may be set, reflecting histories of events and teacher characteristics, our data allow us to explore how teachers may pursue new expertise to respond to immediate accountability pressures or emphasis on standards.

A teacher may seek interaction with knowledgeable others—those who have expertise in implementing certain practices or increasing test scores. Coburn, Mata, and Choi (2013) found that teachers began to seek out colleagues with more mathematics instructional expertise, defined as participation in intensive mathematics professional development, when their district adopted a new mathematics initiative built around the adoption of a new standards-based curriculum. Further, when some of the related supports (e.g., coaching and time for collaboration) were removed, teachers continued to focus their advice seeking on colleagues with mathematics instructional expertise. Similarly, we might expect that simultaneous accountability pressure and emphasis on standards-based teaching place competing demands on teachers and influence where they go for help with their instruction. In particular, teachers might seek different forms of advice or expertise depending on whether their school emphasizes test scores or standards-based (i.e., inquiry-oriented) mathematics instruction. In this study, we investigate:

Research Question 1: To what extent does a colleague's expertise factor into mathematics teachers' decision making about whom to seek new advice from in the context of districts that are experiencing both accountability pressures and emphases on standards-based instruction?

Research Question 2: Does a teacher's own expertise moderate the influence of a colleague's relative expertise on new advice seeking?

Methods

Data

Data for this analysis came from a longitudinal study of teachers and schools in four, large urban school districts with a stated goal of raising student achievement by improving teachers' ability to implement inquiry-oriented instructional practices (Cobb & Jackson, 2011; Cobb & Smith, 2008). These inquiry-oriented practices were consistent with those described in the NCTM standards. The selection of the four districts for this larger study was driven by three criteria: (a) The districts had identified middle school mathematics as a priority area and developed an improvement plan; (b) the districts had adopted a middle school mathematics curriculum, consistent with their goals and the NCTM standards, that affords teachers opportunities to foster students' conceptual understanding of central mathematical ideas (e.g.,

Table 1
Schools and Adequate Yearly Progress (AYP) Status by District

District	*N* Schools in Sample	*N* Met AYP	*N* Failed to Meet AYP for 4 or More Consecutive Years
A	10	1	7
B	7	2	3
C	6	2	3
D	7	0	7

Connected Mathematics); and (c) the districts' improvement plans included ongoing teacher professional development organized around the instructional materials and focused on both mathematical content and student learning. All four districts served large numbers of students in an urban context, with the smallest district serving 35,000 students and the largest over 160,000. Each of the four districts served a diverse population of students, though the specific racial/ethnic distribution varied; in only one district did the student population contain a majority of White students. In addition, in all four districts large proportions of students received free or reduced price lunch (approximately 68% of the students were eligible for free or reduced price lunch, ranging from 55% to 85% across the four districts). All four districts employed mathematics instructional coaches in some capacity. In one of the districts, the coaches worked as coaches half of the time and teachers the other half of the time. These coaches are included in our analysis because of their role as teachers as well. All other non-teaching coaches are excluded from this analysis as our focus is on understanding to whom teachers go for instructional advice within their teaching network. In our analyses, we control for whether a teacher is also a formally designated coach because of the evidence that formal roles do influence teachers' advice seeking (Moolenaar et al., 2014; Spillane et al., 2012; Spillane et al., 2015).

As is typical of large, urban districts across the United States, schools in our study were experiencing considerable pressure related to the No Child Left Behind Act (NCLB, 2002) and being held accountable for all students making adequate yearly progress. See Table 1 for information about the number of schools and their AYP status in 2010. The majority of the schools in our sample were at a stage where they were identified for corrective action, which could have potentially resulted in some teachers losing their jobs if the schools were restructured. Only 5 of the 30 schools met AYP during the study period. Therefore, it is likely that teachers and administrators in our study schools felt some pressure for their students to perform well on state tests.

For the purpose of this study, we used data collected in the 2008–2009 and 2009–2010 school years, including interviews, surveys, classroom observations, and student achievement data.

Outcome Measure

Our primary source of data is surveys of teachers' advice-seeking behavior. Via an online survey, we asked teachers to whom they turned for advice or information about teaching mathematics. Teachers could list up to 10 people they sought advice from, but only 1.2% of teachers listed as many as 10. In network language, the teacher who took the survey is called the *ego*, and the person who they nominate as someone from whom they seek advice is called the *alter*, which results in a *tie* between ego and alter. Any one ego can have multiple alters or ties, and ties can be reciprocal (i.e., teachers nominate each other).

We assume that a tie is possible for every pair of mathematics teachers in a school and use a dichotomous outcome of whether or not a particular ego (i.e., teacher) nominates another teacher as an alter, which would indicate that the ego seeks advice about mathematics instruction from the alter. Our dependent variable is the presence of a mathematics instructional advice-seeking tie between two teachers in the 2009–2010 school year. For every pair of mathematics teachers i and j, if i turned to j for advice about teaching mathematics, the $i \longrightarrow j$ relationship was assigned a value of 1 and 0 otherwise. As we describe in greater detail in the following, we removed reciprocal ties (i.e., teachers listed each other as members of their advice networks) and ties that were not new from the sample.

Our sample includes 368 pairs of colleagues for 109 teachers across 27 schools because this was the sample of individuals and pairs for whom we had complete data. A comparison between our sample and the full sample is given in Table 2. There are no significant differences between samples. In the following, we describe each of the measures used as independent variables in this analysis. Table 3 gives descriptive statistics for the additional measures (beyond what is described in Table 2) for our sample.

Focal Expertise Measures

We consider the measures detailed in the following as proxies for different forms of mathematics teacher expertise. As described previously, we include both measures that attempt to capture aspects of situated knowledge or practice as well as more observable (to other teachers) measures of teacher expertise. For each of these measures, we model them at the ego level (representing controlling for a teacher's own expertise) and at the pair level (representing the relative difference between ego and alter). The creation of several of the measures of situated knowledge or practice involved quantitizing qualitative data (Sandelowski, Voils, & Knafl, 2009). The specific quantitizing processes are described in the following.

Inquiry-Oriented Instruction

As described previously, we focused our observations of teachers' instructional practice on mathematically challenging tasks and related whole-class

Table 2
Description and Comparison of Analytic Sample

	Full Teacher Sample			Analytic Sample			
	M or %	*SD*	*N*	*M* or %	*SD*	*N*	*t* Test
Individual level							
Female	69.88		249	69.72		109	0.019
White	55.42		249	59.63		109	−0.738
Black	32.13		249	26.61		109	1.066
Novice	34.40		241	37.60		109	−0.573
Experience teaching mathematics	9.228	8.604	241	9.606	9.251	109	−0.371
Inquiry-oriented instruction	2.109	0.477	146	2.037	0.455	109	1.208
Mathematical knowledge for teaching	2.896	0.778	157	2.776	0.737	109	1.264
Instructional vision	2.283	0.604	158	2.214	0.589	109	0.920
Student achievement gains	−0.009	0.149	170	−0.016	0.160	109	0.372
Perceived test score pressure from principal	2.075	0.566	138	2.107	0.576	109	−0.456
School level							
Schools in District A			10			7	
Schools in District B			7			7	
Schools in District C			6			6	
Schools in District D			7			7	
Number of math teachers in school	9.40	4.381	30	11.42	3.182	27	

Table 3
Descriptive Statistics for Pair-Level Measures

	M	*SD*	Minimum	Maximum
Dependent variable				
Presence of advice seeking	.073	0.261	0.00	1.00
Control factors				
Same gender	.546	0.499	0.00	1.00
Same race	.641	0.480	0.00	1.00
Same grade assignment	.304	0.461	0.00	1.00
Same collaborative meeting	.853	0.354	0.00	1.00
Alter is a coach	.052	0.222	0.00	1.00
Colleague expertise factors				
Relative inquiry-oriented instruction	−.015	0.590	−1.58	1.58
Relative mathematical knowledge for teaching	.005	0.965	−2.40	2.40
Relative instructional vision	−.002	0.839	−2.40	2.40
Relative student achievement gains	.000	0.233	−0.67	0.67
Relative experience teaching mathematics	−.481	11.040	−36.00	31.00

Note. Recall that relative expertise is defined as alter expertise – ego expertise for each of the colleague expertise factors.

discussions because those were the foci of instructional reforms in the participating districts. This measure is derived from a set of rubrics designed to measure the quality of teachers' instructional practice: the Instructional Quality Assessment (IQA; Boston & Wolf, 2006; Matsumura et al., 2006). We used these rubrics to code video recordings of two consecutive days of classroom instruction for each of the participating teachers in late winter of each year. The IQA was developed at the University of Pittsburgh's Learning Research and Development Center. The two primary domains of the IQA are Academic Rigor and Accountable Talk. The Academic Rigor rubrics assess the cognitive demand of classroom activity over the course of the lesson. The Accountable Talk rubrics focus on specific aspects of discourse during the whole-class discussion after students have had a chance to work on solving the task. We use eight IQA rubrics, three of which pertain to Academic Rigor, and five pertain to Accountable Talk (see Appendix in the online journal for details).

Coders were trained by the instrument developer and required to reach 80% interrater agreement before beginning coding. We measured the coding reliability by calculating both percentage exact agreement between raters and a kappa statistic (Cohen, 1960). The average percentage agreement across the eight rubrics for the four years was 71.2%, with an average kappa score of 0.46. Given the complexity of these measures, these reliability scores are sufficient to discern differences in learning opportunities for students (Hartmann, Barrios, & Wood, 2004; Landis & Koch, 1977). We combined these eight rubrics to create two subscores and one overall IQA score for each lesson. The two of the three Academic Rigor rubrics that pertain to the cognitive demand of the task as posed and as implemented (Task Potential and Task Implementation, respectively) were averaged to create the Task subscore. The other six rubrics, which all pertain to the concluding whole-class discussion, were averaged to create the Discussion subscore. Finally, the Task and Discussion subscores were averaged to create an overall IQA score. This gives a score that could range from 0 to 4, with 0 representing more traditional instruction and 4 representing inquiry-oriented instruction.

Mathematical Knowledge for Teaching

Recall that MKT is mathematics content knowledge specific to the work of teaching (e.g., common misunderstanding of fractions; multiple ways that students can solve the same problem and get a mathematically correct answer) and goes beyond content knowledge that others fluent in mathematics know (Hill, 2007). Previous research has demonstrated that teachers' MKT is positively related to student achievement and aspects of teachers' instructional practice (Hill, Ball, Blunk, Goffney, & Rowan, 2007; Hill et al., 2008). In March of each year of the study, we assessed each participating teacher's MKT by using a pencil-and-paper instrument developed by the Learning Mathematics for Teaching project at the University of Michigan (Hill, Schilling, & Ball, 2004). The instrument was tested for external validity, and the developers reported a reliability index of .70 or above from a pilot administration of the assessment to a national sample of approximately 640 practicing middle school teachers (Hill, 2007). We used the instrument to assess teachers' common content knowledge and specialized content knowledge with respect to two dimensions: (a) number concepts and operations and (b) patterns, functions, and algebra. For each of the two subtests, raw scores were translated into item response theory (IRT) scale scores. For our analysis, we use a combined average of these two subtest item response theory scale scores to form a single MKT score for participating teachers in each study year.

Instructional Vision

To understand teachers' instructional visions (Munter, 2014), teachers were asked what they would look for when observing another mathematics teacher's instruction to determine if the instruction was of high quality. Depending on the breadth of their responses, teachers were then asked a series of probes. Teachers' responses to the interview questions were coded on several different dimensions (that correspond with interview probes): the role of the teacher, mathematical tasks, classroom activity, and discourse (including the structure, the nature of talk, teacher questions, student questions, and student explanations; see Appendix in the online journal for details). For each rubric, scores ranged between 0 and 4. Teachers who describe more traditional instruction are at the bottom of the scale, and the top of the scale is inquiry-oriented instruction that includes cognitively demanding tasks, rich whole-class discussions, and a proactive role of the teacher in guiding these activities. Coders were trained by the developer of the measure and expected to reach an 80% agreement level prior to beginning coding. Overall, the ongoing reliability percentage exact agreement between coders was 80%.

To estimate teachers' instructional vision, we calculated the mean across the scored dimensions (i.e., if only two dimensions received scores, then the mean would be calculated across those two dimensions). Mean scores can be interpreted on the original scale from 0 to 4, with 0 indicating more traditional instruction and 4 indicating more inquiry-oriented instruction.

Student Achievement Gains

This measure is derived from multilevel models of student achievement gain scores and was designed to account for the type of information that teachers might have access to with respect to their colleagues' students' achievement. In these models, we do not control for any student or class characteristics because this is consistent with how teachers might make these assessments of their colleagues' performance in their heads. The student gain scores are the difference between the score in the current year and the score in the prior year. For each teacher, the student achievement gains score is the teacher-level random effect estimate derived from the model; it represents the teachers' average deviation from the school average gain score.

Experience Teaching Mathematics

Teachers reported their years of experience teaching mathematics, and we used these self-reports of experience to account for their experience teaching, one of the more observable measures of expertise. As with all of the measures of expertise, we used this to calculate relative experience teaching mathematics and ego experience teaching mathematics. With respect to the ego expertise measure, we expected a teacher's own expertise to be primarily driven by whether they are a novice or not, so instead of including experience teaching mathematics in years as a continuous variable for egos, we included a dummy variable indicating whether teachers were in their third year of teaching or less (Novice).

Ego-Level Controls

Perceived Test Score Pressure From Principal

To account for teachers' perceptions of the accountability pressure in their school, we included a measure of teachers' perceptions of principal expectations specific to students' test scores. This measure came from a teacher survey item that asks the extent to which the principal expects them to make sure their students' test scores are high. Response options included *not at all* (0), *to a small extent* (1), *to a moderate extent* (2), and *to a great extent* (3). Perceived test score pressure from the principal was treated as continuous in this analysis.

Female

We included a dummy variable to indicate whether teachers were female.

White

We included a dummy variable to indicate whether teachers identified their race as White or some other race.

Pair-/Alter-Level Controls

Same Gender

This is a dummy variable indicating whether the pair of teachers is the same gender.

Same Race

This is a dummy variable indicating whether the pair of teachers is the same race.

Alter Is a Coach

This is a dummy variable indicating whether the alter is a part-time coach.

Same Grade Level

This is a dummy variable indicating whether the pair of teachers teach the same grade level. If teachers taught more than one grade level (e.g., seventh and eighth), then that teacher would be categorized as teaching the same grade level as the other teachers at all of those grade levels (e.g., the seventh- and eighth-grade teachers) in that school.

Same Collaborative Meeting

This is a dummy variable indicating whether the pair of teachers jointly participates in a meeting focused on instruction.

School-Level Controls

District Membership

This is a set of dummy variables indicating in which district teachers are members. The reference district is District C because of more contextual differences between District C and the other districts.

Number of Math Teachers

This is a continuous variable indicating the number of mathematics teachers in the school.

Data Analysis

To focus on the development of new, directed ties, we use the development of a new tie as the outcome variable and remove pairs if they had existing ties in the prior year or reciprocal ties between a pair in the current year.[1] By removing pairs of colleagues that previously had a tie, we reduced the risk of omitted variable bias by removing the possibility of existing relationships, formed for unknown reasons, as the basis for a tie, and focus on the generation of new ties. Earlier, we argued that forming a new tie represents teachers' current adjustments to social networks. Further, because we were interested in how relative expertise influences teachers' advice seeking, we ruled out reciprocal ties as well. By definition, reciprocal ties represent relationships in which expertise flows regardless of which teacher holds greater expertise of a particular type.

We begin by examining correlations between our measures of expertise. This analysis is used to confirm that the multiple measures of expertise that we employ in our models are tapping different aspects of expertise, thus allowing us to examine the relative impact of different kinds of expertise on advice seeking behavior. The set of analyses reported in this article focus on 109 middle school mathematics teachers and their mathematics-teaching colleagues in 27 schools.

Network Dependency

When modeling pair-wise network data, the assumption of independent observations is violated. For example, one teacher may be the target of advice seeking more than other teachers. Therefore, it is a standard procedure in network analyses to account for potential dependencies in network data. There are several approaches that have been identified and developed to account for dependency by applying either a dyad-independent assumption or a Markov dependence assumption (Holland & Leinhardt, 1981; Robins, Pattison, Kalish, & Lusher, 2007; Robins, Snijders, Wang, Handcock, & Pattison, 2006; Snijders, Pattison, Robins, & Handcock, 2006). In this study, we focus on processes through which teachers are more likely to seek advice through new and nonreciprocal ties in the 2009–2010 school year (Time 2) that were not reported in the 2008–2009 school year (Time 1), which results in a significantly reduced sample. Our use of the reduced sample likely accounted for some proportion of the structural dependencies because we removed some of the ties that contribute to dependence (e.g., the reciprocal ties), but it did not adjust for the dependencies associated with the distribution of ties in the network.

To address the residual structural dependencies, we adopted the approach of Snijder et al. (2006) of using geographically weighted degree statistics to adjust for network dependencies by using weights that are a function of alter's in-degree and ego's out-degree distribution (i.e., the number of people who seek advice from them and the number of people they seek advice from, respectively; see Technical Appendix in the online journal for more details). In addition, we controlled for ego-level and school-level random effects, which allow the variability of general tendencies in seeking advice to vary for individuals and within schools.

Analytic Strategies

In order to model the formation of new advice-seeking ties, three-level hierarchical generalized linear models (HGLM) were employed to estimate the presence of new ties nested within a series of pair-level (Level 1), ego-level (Level 2), and school-level characteristics (Level 3). New advice-seeking ties were defined as those nonreciprocal advice ties in the 2009–2010 school year (Time 2) that were not reported in the 2008–2009 school year (Time 1). We modeled the likelihood of formation of new ties based on alter's relative expertise and a number of pair-, ego-, and school-level control variables (including ego's own expertise).

We estimated several different models to examine our main research question. First, our baseline model includes demographic, contextual variables and measures of the ego's expertise but does not include any of the measures alter's expertise. We then report the results of a combined model that adds pair relative expertise measures.[2] Finally, we were also interested in how the level of ego expertise influences the impact of the pair relative expertise on decision making, so we estimated models that added the interaction between ego expertise and pair relative expertise. These models examine the degree to which the impact of relative expertise on advice seeking is conditional on the level of expertise of the seeker. For example, were teachers who were poor at improving student test scores more likely to seek others who were better at improving test scores? We only report results for the interactions with relative expertise in improving student achievement but comment on the results from the other modeled interactions.

Formally, with Equation 1, we examine the likelihood of a teacher forming a new advice-seeking relation given relative expertise of colleagues, controlling for teachers' demographic information, homophily, and aspects of the school and district context. θ_{0ij} indicates the average tendency of ego's advice seeking in school j. θ_1 - θ_{4i} capture the homophily effects of gender, race, grade level, and meeting co-participation. Positive coefficients would denote that teachers were more likely to seek advice from colleagues who share a characteristic or experience. The term θ_5 is the only alter-specific attribute and applies only to teachers who served as part-time mathematics coaches. The terms θ_6 through θ_{10} are our focal parameters; they describe the extent to which alters' relative expertise increases the likelihood of new advice-seeking behavior. In addition, at Level 2 we examine the influence of teachers' individual characteristics, such as female, White, novice, and perceived testing pressure. At Level 2, we also examine the influence of ego expertise for our five different measures of expertise.

All models include a random intercept, which allows the tendency of new advice seeking to vary across individuals *i* and schools *j*. We also controlled for the number of mathematics teachers in the schools and used district fixed effects to adjust for potential differences due to district contexts in Equation 3.

Level 1: pair or alter:

$$\log\left[\frac{p\left(\text{New advice seeking}_{ii'j}\right)}{1-p\left(\text{New advice seeking}_{ii'j}\right)}\right]=\theta_{0ij}$$
$$+\theta_{1-4}(\text{Same gender/same race/same grade level/same collaborative meeting})_{ii'j}$$
$$+\theta_5(\text{Alter is a coach})_{ii'j}$$

expertise seeking: informal:

$$+\theta_6(\text{Alter's experience teaching mathematics}_{i'}-\text{Ego's experience teaching mathematics}_i)_j$$
$$+\theta_7(\text{Alter's inquiry}-\text{oriented instruction}_{i'}-\text{Ego's inquiry}-\text{oriented instruction}_i)_j$$
$$+\theta_8(\text{Alter's mathematical knowledge for teaching}_{i'}-\text{Ego's mathematical knowledge for teaching}_i)_j$$
$$+\theta_9(\text{Alter's instructional vision}_{i'}-\text{Ego's instructional vision}_i)_j$$
$$+\theta_{10}(\text{Alter's student achievement gains}_{i'}-\text{Ego's student achievement gains}_i)_j. \quad (1)$$

Level 2: ego:

$$\theta_{0ij}=\beta_{00j}+\beta_{01j}(\text{Female})_{ij}+\beta_{02j}(\text{White})_{ij}+\beta_{03j}(\text{Perceived test pressure})_{ij}$$
$$+\beta_{04j}(\text{Novice})_{ij}$$
$$+\beta_{05j}(\text{Inquire}-\text{oriented instruction})_{ij}+\beta_{06j}(\text{Mathematical knowledge for teaching})_{ij}$$
$$+\beta_{07j}(\text{Instructional vision})_{ij}+\beta_{08j}(\text{Student achievement gains})_{ij}+U_{0ij}. \quad (2)$$

Level 3: school:

$$\beta_{00j}=\gamma_{000}+\gamma_{001}(\text{Dis A})_j+\gamma_{002}(\text{Dis B})_j+\gamma_{003}(\text{Dis D})_j$$
$$+\gamma_{004}(\text{Number of math teachers})_j+v_{00j}. \quad (3)$$

Results

Our first analysis was to correlate our measures of expertise. Those correlations are shown in Table 4. There were two statistically significant

Table 4
Correlation Table for Potential Teacher Expertise in Teacher Network

	(1)	(2)	(3)	(4)	(5)
(1) Experience teaching mathematics	1.000				
(2) Inquiry-oriented instruction	−0.074	1.000			
(3) Mathematical knowledge for teaching	0.045	0.053	1.000		
(4) Instructional vision	0.057	0.096†	0.056†	1.000	
(5) Student achievement gains	−0.144**	0.136**	−0.083	0.085	1.000

†$p < .10$. **$p < .01$ (two-tailed test).

correlations that involved the ability to improve student achievement. One of those statistically significant correlations was a negative correlation between years of experience teaching mathematics and student achievement gains ($r = -0.144$, $p < .01$). In other words, teachers with more experience tended to be less effective in improving student achievement as measured by gains in standardized tests. Another significant correlation was between student achievement gains and inquiry-oriented instruction ($r = 0.136$, $p < .01$). In this case, teachers who were better at improving student achievement tended to be better at enacting inquiry-oriented instruction. Given the small size of the correlations, we do not have to worry about collinearity between these measures and included them in models together. Overall, these different measures of expertise do seem to measure different forms of expertise.

The results of our baseline and teacher expertise selection models are reported in Table 5. First, we examine the baseline model omitting the measures of relative expertise of the alter. There is evidence that a number of our control variables are related to teacher selection of new advice. At the ego level, whether the teacher was a female and several measures of teacher expertise were significant. In our sample, female teachers were less likely to seek new advice (coefficient = −1.638; $p < .05$), novices were more likely to seek new advice (coefficient = 1.459; $p < .05$), and teachers with less developed mathematical knowledge for teaching were more likely to seek new advice (coefficient = −1.198; $p < .05$). At the alter and pair levels, teachers were more likely to seek new advice from colleagues who taught the same grade level and colleagues who were designated as coaches (coefficient = 2.853 and coefficient = 4.274, respectively; $p < .001$). Contrary to other research, we found no homophily effect of gender or ethnicity or effect for co-participation in meetings. We discuss these results in greater detail in the discussion section. Finally, there is one marginally significant result that is important to note: Teachers with greater capacity to teach in inquiry-oriented ways were more likely to seek new advice (coefficient = 1.305; $p < .10$).

Table 5

Three-Level Teacher Advice-Seeking Selection Models in Four Urban Districts

	Baseline Model				Teacher Expertise Main Model			
	b[a]	*SE*	Odds Ratio	STD[b]	*b*	*SE*	Odds Ratio	STD
Intercept	−1.241	1.373	0.289		−1.746	1.387	0.174	
Level 1: Pair or alter								
Same gender	−0.285	0.581	0.752		−0.270	0.618	0.763	
Same race	−0.246	0.610***	0.782		−0.316	0.624	0.729	
Same grade level	2.853	0.620	17.344		3.232	0.696***	25.330	
Same collaborative meeting	−0.072	0.927	0.931		0.312	0.945	1.366	
Alter is a coach	4.274	1.164***	71.808		3.822	1.218**	45.696	
Teacher expertise factors								
Relative experience teaching math					0.070	0.054	1.072	0.358
Relative inquiry-oriented instruction					−0.012	0.724	0.988	−0.059
Relative math knowledge for teaching					−0.201	0.576	0.818	−0.132
Relative instructional vision					−0.234	0.546	0.791	−0.138
Relative student achievement gains					4.756	2.105*	116.280	1.086
Level 2: Ego								
Female	−1.638	0.684*	0.194		−1.901	0.723*	0.149	
White	0.257	0.721	1.293		0.255	0.706	1.291	
Perceived test pressure	0.286	0.473	1.331	0.451	0.289	0.491	1.335	0.453
Novice	1.459	0.725*	4.301		1.347	0.742†	3.844	
Inquiry-oriented instruction	1.305	0.732†	3.689	0.713	1.477	0.700*	4.379	0.811
Mathematical knowledge for teaching	−1.198	0.533*	0.302	−0.728	−1.476	0.575*	0.229	−0.913
Instructional vision	0.395	0.488	1.484	0.250	0.521	0.501	1.684	0.303
Student achievement gains	−0.757	2.056	0.469	0.142	−1.849	2.227	0.157	0.006

(continued)

Table 5 **(continued)**

	Baseline Model				Teacher Expertise Main Model			
	b^a	*SE*	Odds Ratio	STD[b]	*b*	*SE*	Odds Ratio	STD
Level 3: School								
District A	0.562	1.409	1.754		1.015	1.412	2.759	
District B	−2.682	1.164*	0.068		−2.108	1.172†	0.121	
District C	−1.263	1.025	0.283		−0.896	1.018	0.408	
Number of math teachers	−0.157	0.103	0.855	−0.473	−0.153	0.099	0.858	−0.429

Note. Each model also controls for geographically weighted degree statistics (Snijders, Pattison, Robins, & Handcock, 2006) to adjust for network dependency (see Appendix in the online journal for more details).
[a]Unstandardized estimates.
[b]Standardized estimates for continuous variables.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Our main focus, however, is on the degree to which teachers seek advice from colleagues who are more expert in five different types of expertise—years of teaching experience, capacity to enact inquiry-oriented instruction, mathematical knowledge for teaching, instructional vision, and ability to improve student achievement. These results are shown in the second set of columns of Table 5. Our relative expertise model suggests that teachers are more likely to seek advice from colleagues who had better relative student achievement gains rather than other forms of expertise. If we compare two pairs of teachers who are similar in other ways but differ by one standard deviation of alter's relative student achievement gains, we expect that the odds of advice seeking is 2.962 times (standardized coefficient = 1.086, $p < .05$) larger than the odds of mathematics advice seeking of a similar pair of teachers who share the same capacity to improve student achievement. We also found that when controlling for relative expertise of alters, the ego expertise effects found in the baseline model persisted or became stronger: Teachers with higher inquiry-oriented instruction scores were more likely to seek advice and teachers with lower mathematical knowledge for teaching scores were more likely to seek advice. These results are interpreted in the discussion.

Pertaining to our interest in whether relative expertise influences advice seeking behavior more when a teacher's own level of expertise is high or low, we examined several interaction models (see Table 6). We found only one significant interaction effect: Teachers with more inquiry-oriented instruction were more likely to seek out other teachers who were relatively more successful at improving student achievement when compared with teachers with less inquiry-oriented instruction. In other words, the likelihood of seeking advice from teachers who were more able to improve student achievement depended on the quality of the advice seekers' inquiry-oriented instruction. This relationship is shown in Figure 1. The effect of an alter's relative student achievement gains is positive for egos with high inquiry-oriented instruction scores and essentially zero for egos with low inquiry-oriented instruction scores. Thus, egos with more inquiry-oriented instruction seem to discriminate among colleagues based on relative student achievement gains expertise while egos with less inquiry-oriented instruction do not. We also examined ego expertise interactions for relative inquiry-oriented instruction, mathematical knowledge for teaching, instructional vision, and years of mathematics teaching experience—but none of the interactions were statistically significant.

In summary, teachers who showed greater capacity to teach in inquiry-oriented ways were more likely to seek new mathematics instructional advice from their school colleagues, and they tended to seek advice from colleagues in their school who have more success in improving student achievement. In other words, teachers who were already more developed in their capacity to teach inquiry-oriented mathematics were more likely to seek advice from colleagues who were more expert in improving student

Table 6
Models Testing Interaction of Ego Expertise With Relative Gains Expertise

	Gains Model (a)		Gains Model (b)		Gains Model (c)		Gains Model (d)	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Intercept	−2.907	1.293*	−3.386	1.277*	−3.053	1.276*	−3.511	1.303*
Control factors								
Same gender	−0.468	0.616	−0.374	0.586	−0.474	0.592	−0.308	0.581
Same race	−0.165	0.637	−0.277	0.627	0.055	0.603	0.004	0.606
Same grade	2.768	0.604***	2.989	0.642***	2.714	0.592***	2.694	0.587**
Same collaborative meeting	−0.076	0.975	0.446	0.967	0.035	0.955	0.254	0.966
Alter is a coach	3.663	1.171**	3.593	1.127 *	3.185	1.069*	3.059	1.120**
Relative math teaching experience	0.024	0.050	0.029	0.050	0.021	0.047	0.021	0.048
Teacher expertise								
Relative student achievement gains	1.905	1.988	4.061	2.057*	3.230	1.928†	2.737	1.908
Relative Gains × Ego Instruction (a)	11.425	5.185*						
Relative Gains ×Ego MKT (b)			0.869	3.195				
Relative Gains ×Ego Vision (c)					1.002	2.919		
Relative Gains × Ego Gains (d)							14.950	11.819
Level 2: Ego								
Female	−0.804	0.707	−1.029	0.704	−0.543	0.679	−0.520	0.669
White	−0.081	0.755	−0.092	0.751	−0.363	0.724	−0.408	0.725
Perceived test pressure	1.219	0.674†	0.767	0.603	1.133	0.654†	1.369	0.687*
Novice	1.400	0.739†	1.427	0.720*	1.198	0.733	1.412	0.720†
Inquiry-oriented instruction (a)	1.460	0.946						
MKT (b)			−1.379	0.608*				
Instructional vision (c)					0.458	0.563		
Student achievement gains (d)							1.005	2.084

(continued)

Table 6 **(continued)**

	Gains Model (a)		Gains Model (b)		Gains Model (c)		Gains Model (d)	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Level 3: School								
District A	−0.055	1.511	0.228	1.467	0.417	1.465	0.680	1.487
District B	−3.083	1.134*	−3.078	1.121*	−2.688	1.038*	−2.668	1.065*
District C	−1.845	1.084	−1.668	1.052	−1.655	1.005	−1.506	1.035
Number of math teachers	−0.193	0.112†	−0.172	0.102	−0.135	0.104	−0.145	0.105

Note. Each model also controls for geographically weighted degree statistics (Snijders, Pattison, Robins, & Handcock, 2006) to adjust for network dependency (see Appendix in the online journal for more details). MKT = mathematical knowledge for teaching.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

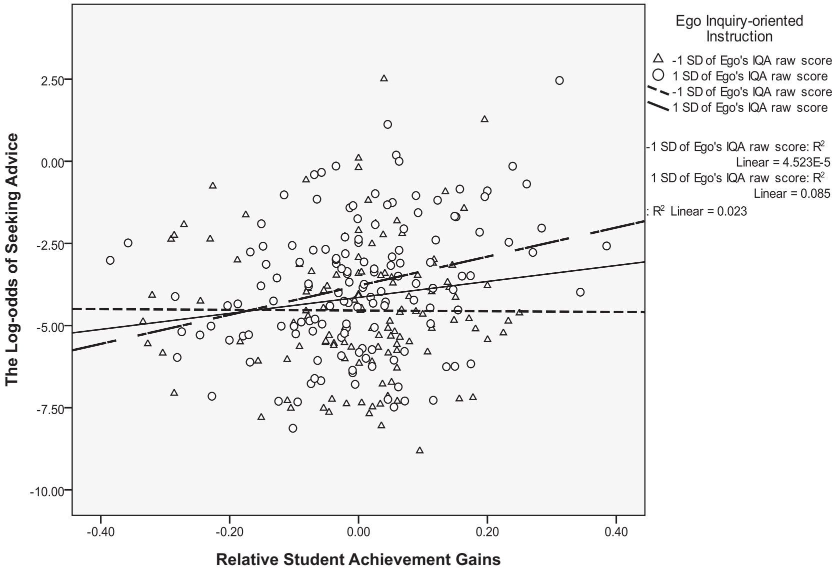

Figure 1. **Interaction between ego inquiry-oriented instruction and relative student achievement gains: The probability of advice seeking based on alter's relative ability to improve student achievement conditional on the teacher's own capacity to enact inquiry-oriented instruction.**

achievement than teachers who showed lower capacity to implement inquiry-oriented mathematics instruction. Possible interpretations of these results are discussed in the following.

While our primary focus was on selection of new advice-seeking ties based on expertise, an important aspect of the context was that the schools in our study were experiencing considerable accountability pressure. To control for variation in teachers' perceived testing pressure, we included a measure of teachers' perceptions of testing pressure from the principal. In our main model (see Table 5), we did not find a significant effect of perceived testing pressure (b = 0.286, p = .589). We suggest possible interpretations of this result in the discussion.

Discussion

Teachers' interactions with other teachers in their social network have the potential to support their learning, making it critical for researchers and practitioners to understand how teachers' social networks form. While prior research emphasizes the role of homophily in network formation (i.e., attraction to others teachers of the same gender, race, or who teach the same grade level), much less is known about the role of expertise and external expectations for teachers in the formation of advice-seeking networks. Results from this study point to the forms of colleagues' expertise and the accountability that can play a role in teachers' decisions about whom to seek advice from. As a number of studies have demonstrated that teachers learn through their advice-seeking interactions with colleagues (Frank et al., 2004; Penuel et al., 2010; Sun et al., 2013, 2014), understanding how networks form is critical for increasing learning opportunities in schools. Further, there is evidence that social network interactions are emergent and cannot be completely designed or mandated (Smylie & Evans, 2006; Spillane, Reiser, & Gomez, 2006). Consistent with other recent studies (e.g., Coburn et al., 2013), our findings suggest that the policy context can influence teachers' advice seeking, especially when it comes to decisions about whom teachers turn to when they are looking to improve their instructional practices.

Before discussing our findings in greater detail, we describe several limitations of this analysis with respect to modeling and the sample. Certainly factors besides differences in level of expertise could be responsible for some of the trends we observe in our data. But we note that the relative expertise effects are related to *changes* in advice seeking. Therefore, any static aspect of the pair of actors that was manifest at Time 1 (e.g., differences in race or gender) was controlled for (for the value of controlling for prior measurements in approximating the results from randomized experiments in educational research, see Steiner, Cook, Shadish, & Clark, 2010).

Nonetheless, one might raise the concern that unmeasured factors could be responsible for change in implementation. While we cannot control for unobserved factors in our model, we report what the characteristics of the unobserved factors would have to be to invalidate our inference of an effect of differences in expertise on instructional advice. Based on our main finding in Table 5, to invalidate our inference of an effect of relative expertise on instructional advice, we would need to replace about 12.95% (about 48 pairs) of relative student achievement gains pairs with other pairs in which there was no effect of relative student achievement gains expertise on advice sought (Frank, Maroulis, et al., 2013).[3] While this is a relatively small effect, it indicates that particular forms of expertise matter, and this should be investigated with larger samples in the future.

A related set of limitations of this analysis pertains to the sample. In particular, the size and nonrandom nature of the sample also limit our ability to generalize from this analysis. Although our sample compares favorably to other network analyses where observational, interview, and assessment data are used to generate measures for both the ego and the alter, our focus on new, nonreciprocal ties for which we had information about expertise for the pair dramatically reduced our sample size. Despite these limitations, we feel that the findings from this study provide some indication that colleagues' expertise and the accountability context play a role in teachers' advice-seeking decisions.

In this analysis, we set out to understand how colleagues' expertise influences teachers' decision making about whom to seek advice from in the context of school districts focused on instructional improvement while experiencing considerable accountability pressure. Our analyses with different measures of expertise suggest that teachers do consider the expertise of others when seeking advice. This general finding is consistent with reports from teachers in other studies stating that expertise is an important factor in their decisions of whom to seek advice from (e.g., Coburn et al., 2010; Spillane et al., 2015; Spillane, Hallett, & Diamond, 2003) and a study suggesting that teachers' participation in professional development, considered as an indicator of expertise, influences teachers' social network selection (Spillane et al., 2012).

We believe that this study is the first to consider multiple types of expertise in modeling teachers' advice-seeking behavior, finding that different types of expertise factor into teachers' advice seeking in different ways. We were particularly interested in how the relative expertise of colleagues factors into teachers' new advice seeking. We found that colleagues' ability to improve student achievement was significantly related to advice seeking when controlling for leadership positions, experience, and other forms of expertise. In particular, teachers were more likely to seek new advice from colleagues who were better at improving student achievement. In contrast, relative differences in other forms of expertise were not associated with advice seeking. In other words, rather than considering colleagues' mathematical knowledge for teaching, capacity for inquiry-oriented instruction, vision of high quality mathematics instruction, and years of experience teaching mathematics, teachers in our sample were more likely to consider a colleague's relative ability to improve student achievement.

The significance of colleagues' relative ability to improve student achievement is not surprising given the accountability context of the schools within our study. First, given that the majority of the schools in our sample were in an NCLB stage where they were identified for corrective action, there was considerable pressure for students to perform well on standardized tests at these schools. Second, this measure of expertise was likely to be more visible to teachers than other measures of expertise. For example, it was common in these schools for administrators and teachers to talk about student results on standardized tests (Rigby, Larson, & Chen, 2014). Administrators both made it clear that those scores were valued indicators of teachers' expertise, and they made scores available to other teachers, indicating that expertise was valued and knowledge about the expertise was available (Coburn et al., 2010). Therefore, with an emphasis on those scores and their availability, we see teachers utilizing them to make decisions about new advice seeking. Further, our findings suggest a perhaps unintended consequence of the accountability focus: breaking down traditional barriers against advice seeking (Glidewell, Tucker, Todt, & Cox, 1983; Hargreaves & Dawe, 1990; Lortie, 1975). Teachers in our sample sought out new ties with colleagues who were better at improving student achievement scores, and it is possible that without the accountability focus there would not be an impetus for seeking out those new ties.

Even with the accountability focus in these study schools, we generally did not find a significant effect of perceived testing pressure from the principal. There are several reasons why this might be the case. First, in our sample there might not have been enough variation in this measure to thoroughly investigate relations between perceived pressure and new advice seeking. Second, it could be that this single item does not fully capture the teachers' perceived accountability pressure. We surveyed teachers about the extent to which the principal expects them to make sure their students' test scores are high. Perhaps they feel more accountability pressure from the district or the state given that they might be the entities viewed as holding the school accountable. Future research might investigate the effect of perceived accountability pressure with a more robust scale that accounts for other aspects of the teachers' contexts beyond pressure from the principal.

We also controlled for teachers' own expertise and found that teachers' own expertise influenced their advice-seeking behavior. In particular, novice teachers tended to seek more new advice, teachers with less developed mathematical knowledge for teaching sought more advice, and teachers with greater capacity for inquiry-oriented instruction were more likely to seek advice from other colleagues. Regarding the first finding, it is not surprising that novice teachers tended to seek more new advice because they are likely to perceive themselves as in need of assistance and more of these novices might actually be new to their schools so all of their ties would be considered new ties. Other research has similarly found that less experienced teachers seek more advice (Spillane et al., 2012). One interpretation of the second of these findings, that teachers with less developed mathematical knowledge for teaching were more likely to seek new advice, is that teachers in districts that value inquiry-based instructional methods are motivated to improve their mathematical knowledge for teaching (e.g., different ways that students might solve a problem on the board, common mathematical misunderstandings) by getting help from their colleagues. An interpretation of the third of these findings, with respect to capacity for inquiry-oriented instruction, is that teachers who currently have more capacity for inquiry-oriented instruction are the ones most interested in improving their instruction while teachers whose current methods are more traditional are more satisfied with their current instruction (Gamoran, Secada, & Marrett, 2000).

Lastly, we also investigated how a teacher's own expertise moderates the influence of a colleague's relative expertise on new advice seeking. We found that the more developed a teacher's capacity to teach in inquiry-oriented ways, the more likely they were to seek advice from a colleague who had more success in improving student achievement. We interpret this result in a way consistent with our interpretation of the significant direct effect of an individual teacher's IQA: The capacity to teach in inquiry-oriented ways is perhaps a proxy for a teacher's desire or need to collaborate with other teachers in improving instruction. A fellow teacher's gains on standardized tests may be the most visible signal of expertise, thus driving the advice seeking of teachers who want to work with others to improve.

Combining these results related to the expertise of the colleagues sought and the expertise of the advice seeker suggests several more general interpretations. First, given that the relative ability of colleagues to improve student achievement was associated with advice seeking in our sample, it seems that information about student achievement was both available to them and valued. Borrowing terms from O'Day's (2004) framework on accountability and successful school improvement, through *interaction*, teachers learned about colleagues' abilities to improve student achievement, and through their *interpretation* of colleagues' abilities to improve student achievement, they viewed it as an indicator of expertise. It is unclear how teachers would then act on that information, but it is possible that they shared specific strategies that might have led to school-wide improvement in student achievement.

In contrast, there is no indication that teachers in these schools systematically made decisions about new advice seeking based on their colleagues' capacity for inquiry-oriented instruction, instructional visions, or mathematical knowledge for teaching. These indicators of expertise are likely to be more closely linked to the NCTM standards, which the districts in our study were aiming for in improving instructional practices. Given the lack of influence these indicators of expertise have on advice seeking, it is likely that information about teachers' instructional practice, instructional vision, and knowledge was not sufficiently visible to colleagues or that it was not as valued as a potential support. We discuss the implications of these findings in the following.

While the focus of our analysis was on the role of expertise in teachers' decision making about new advice seeking, we controlled for a number of other factors that have been previously demonstrated to influence teachers' advice seeking. We now compare our findings to those in previous selection models of teachers' advice seeking. First, we found that females were less likely to seek new advice. Prior studies have found that females tend to seek more advice in general (Burt, 1998; Snijders, Lomi, & Torlo, 2013). One possible explanation for our different finding is that we focused on new advice seeking rather than long-standing relationships, and females might tend to have more long-standing advice-seeking relationships. Second, we did not find homophily effects for race or gender. In other words, teachers in our sample did not tend to seek new advice from colleagues of the same race or gender. Our focus on new advice seeking may have contributed to the lack of homophily effects; it could be that homophily contributes more to long-standing ties. Similar to other studies of teachers' social network selection (Frank & Zhao, 2005; Moolenaar et al., 2014; Penuel et al., 2010; Spillane et al., 2012, 2015), we did find a homophily effect when teachers teach the same grade level. Other studies have found that when someone holds a formal leadership position, they are more likely to be sought out for advice (Moolenaar et al., 2014; Spillane et al., 2012, 2015). While our sample focused on teachers, we similarly found that the teachers in one district who served as half-time coaches and half-time teachers were more likely to be nominated for new advice seeking.

Lastly, we did not find that co-participation in meetings was significantly related to new advice seeking. This is a different result from Penuel et al.'s (2010) result demonstrating that teachers who participated in meetings together were more likely to seek advice from one another. One possible reason for this difference is that in our sample, it was common for teachers to co-participate in meetings with other teachers at their school. In fact, approximately 85% of the pairs in our sample co-participated in some sort of meeting focused on instruction, but this could have just been a monthly mathematics department meeting where they actually did not interact closely with every participant in the meeting. It could be that the meetings in which they actually interacted more closely were grade-level meetings and teachers' co-participation in those meetings would have been indicated by the same grade-level variable, which was statistically significant.

Implications

There are several implications of our findings. First, our findings suggest that there may be ways to influence the development of advice-seeking relations. While it is important to consider that networks are emergent phenomena that develop in the course of ongoing interactions (Smylie & Evans, 2006; Spillane et al., 2006), we should not assume that they are unable to be influenced. For example, our findings suggest that with all else equal, if two math teachers teach the same grade level, they are more likely to interact around mathematics instruction. Also, the visibility of expertise and the value placed on student achievement can influence advice-seeking networks. Therefore, our findings are consistent with those of Coburn and colleagues (2010, 2013), which suggest that advice-seeking relations are amenable to contextual influence.

A second and related implication is that given this potential for influence, it is important to find ways to aid teachers in making good expertise-related decisions about advice seeking. For example, if we believe that other forms of expertise are perhaps more aligned with goals for teachers' development, what can we do to make other forms of expertise visible and valued? Baker-Doyle and Yoon (2010) describe "expertise transparency" as "knowledge of the distribution of content knowledge expertise" (p. 115) and advocate for the importance of expertise transparency in the effectiveness of professional development programs. Our findings suggest that expertise transparency could influence teacher learning more broadly through teachers' social networks. There are several ways that expertise could be made more visible.

First, Coburn et al. (2010) found that a mathematics initiative that provided time for teachers to discuss substantive issues around mathematics instruction influenced the extent to which teachers valued mathematics expertise and learned about colleagues' expertise. Baker-Doyle and Yoon (2010) found that by having teachers reveal their content expertise to colleagues on online profile pages, teachers adjusted their advice-seeking behavior to consider that expertise. Another such way to influence teachers' advice seeking is for administrators to place value on particular forms of expertise (Srivastava & Banaji, 2011). Therefore, there is evidence that there are ways to influence teachers' advice-seeking behavior by placing value on particular forms of expertise and making that expertise transparent.

Our study suggests that it is important to carefully consider the forms of expertise that should be valued in schools and specifically design for their transparency. For example, the principal or another school leader might identify particular colleagues who would be good sources of mathematical knowledge for teaching, instructional vision, or inquiry-oriented practice. Another possible way to make instructional expertise visible and valued would be for leaders to make it clear that teachers should be observing each other and looking for particular practices. As teachers observe their colleagues with particular instructional practices in mind, they will begin to identify sources of instructional expertise. Thus, by finding ways to make information about instructional practice, vision, or knowledge more transparent, teachers might use them to make decisions about advice seeking, which is likely to lead to instructional improvement aligned with the standards (e.g., Sun et al., 2014), which will lead to student learning (e.g., Stein & Lane, 1996).

Notes

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[1]Approximately 71.4% of the ties in 2010 were new ties. Of those new ties, 80.8% of them were not reciprocal. Therefore, by eliminating the ties that were not new and were reciprocal, we analyzed approximately 58% of the original sample.

[2]We also estimated models for each measure of expertise separately to investigate potential multicollinearity, but the results did not differ significantly from the combined model so we report only the combined model.

[3]This is about at the median of robustness for articles recently published in *Educational Evaluation and Policy Analysis* (Frank, Maroulis, Duong, & Kelcey, 2013). The proportion of bias to make inference invalid = 100% $\times$ (estimate – (s.e. $\times t_{critical,\,df}$))/estimate.

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