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APPLYING ORGANIZATIONAL RESEARCH TO PUBLIC SCHOOL REFORM: THE EFFECTS OF TEACHER HUMAN AND SOCIAL CAPITAL ON STUDENT PERFORMANCE

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We investigated the effects of teacher human and social capital on growth in student performance in a sample of 1,013 teachers organized into 239 grade teams. We found that teacher human capital that is specific to a setting and task, and some indicators of teacher social capital, predicted student performance improvement. At the team level, average educational attainment and horizontal tie strength were significant predictors of student improvement. We provide some evidence that team horizontal tie strength and density moderate the relationship between teacher ability and student performance. Implications of our multilevel analysis for theory, research, and policy are discussed.

Public schools are organizations in which both intellectual and informational processes are important drivers of performance. The quality of public education has enormous civic and economic consequences and requires large public investments to maintain. In the United States, urban public schools are in trouble by virtually any measure (Schneider & Keesler, 2007). Beginning with the influential report *A Nation at Risk* (National Commission for Excellence in Education, 1983), government officials, business leaders, and parent groups have called for higher performance standards in U.S. public schools on issues ranging from teacher preparation to student achievement. Underlying these calls for reform has been a more fundamental fear that American workers are not being educated in ways that allow them to compete successfully in a global economy (e.g., National Center on Education and the Economy, 2006).

Although a good deal has been written about these issues in education journals, there has been little systematic application of findings from organizational research to this larger policy debate (see Bryk and Schneider [2002] and Ouchi and Segal [2003] for exceptions). Historically, public schools in the United States have treated the teaching of children as an individual endeavor carried out by each teacher within the confines of her or his classroom (Warren, 1975). Thus, enhancing teachers' human capital—such as their classroom competency and experience—has been a subject of particular attention from policy makers. Strong general agreement exists in many sectors, including business, government, and nongovernmental organizations, on the need for "qualified" teachers. However, far less agreement exists on what sorts of qualifications teachers should have and the means to attain them (Darling-Hammond, 2004). Many have pointed to deficiencies in the levels of subject knowledge and pedagogical skill among public school teachers, particularly in urban settings. In response, policy makers have called for various measures to redress these deficiencies, ranging from greater on-the-job professional development, to mandatory testing of teacher subject knowledge, to a fundamental overhaul of college training for aspiring teachers (Finn, 2002; Hill, Campell, & Harvey, 2000; Ravitch, 2000; Schneider & Keesler, 2007). Such measures have put teacher human capital at the center of many school reform efforts (e.g., Sigler & Ucelli Kashyap, 2008).

Practitioners and policy makers have devoted less attention to incentives and regulations that might foster "social capital" within schools. There is growing evidence, however, that teacher collaboration and trust may have as great an effect on student achievement as teacher human capital. For example, Bryk and Schneider (2002) examined reform efforts in the Chicago school district and found that the level of trust among teachers was the

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distinguishing factor in comparisons of schools that thrived under reform and schools that did not. Likewise, in a study of 95 urban schools, we found that the structure and content of relationships among teachers (social capital) significantly predicted school-level student achievement (Leana & Pil, 2006). Moreover, these effects were found in multiple age groups (students in the 5th, 8th and 11th grades) and were sustained over multiple years of student testing. Such findings suggest the potential effect of teacher social capital on student learning and, if confirmed, would have important implications for where public investments in schools might be most effectively made.

In this study, we developed a model of human and social capital in public schools. We examined these phenomena at both the level of the individual teacher and the level of the "grade team," arguing for cross-level effects on the performance of each teacher's classroom of students. We focused on a particular subject, mathematics, because of its centrality in discussions of American global competitiveness and comparative performance (Commission on the Skills of the American Workforce, 1990). We also confined our research to a single subject area because previous studies have indicated that teachers' skill levels and advice networks vary across subject areas (e.g., reading vs. math [Spillane, 1999]). We developed a hierarchical linear model to empirically test our hypothesized relationships and implications for student performance with a sample of 1,013 teachers organized into 239 grade-level teams in 199 public elementary schools.

Our article contributes to both organizational research and public policy. In terms of research, we propose a model of human and social capital that accounts for these constructs' individual and group effects on performance. The literature on schools and the organizations literature more generally contain a substantial body of research on each form of capital examined separately. However, despite a growing acknowledgement that human and social capital coevolve in organizations (e.g., Nahapiet & Ghoshal, 1998; Zuckerman, 1988; Pil & Leana, 2000), researchers have rarely examined their simultaneous effects. Here, we test a theory of human and social capital in which joint effects on performance are proposed.

Second, we contribute to the theory of human capital by considering its task-specific nature and effects. We argue that the value of teacher human capital for student achievement is attributable not so much to general teacher knowledge but, rather, to the content of that knowledge and its applicability to a specific task: teaching mathematics. The distinction between general and firm-specific human capital is a long-standing one (Becker, 1964). As Gibbons and Waldman (2004: 203) noted, however, "Some of the human capital an individual acquires on the job is specific to the tasks being performed, as opposed to being specific to the firm" (2004: 203). Thus, task-specific human capital consists of the knowledge and skills that are applicable to the work being done rather than to a particular organizational context. Here, we examine task-specific human capital and, in this regard, broaden the treatment of human capital theory in organizational research.

Third, in examining social capital in schools, our study contributes to theory and research by simultaneously addressing horizontal and vertical linkages. We account for variability in classroom performance based on the number and strength of ties within teams of teachers (horizontal ties) and on the strength of ties between teachers and their immediate supervisors, typically a school principal or assistant principal (vertical ties). Horizontal ties are typically studied under the rubric of group dynamics or social networks, and vertical ties are largely the purview of research in the leadership domain. We simultaneously examine vertical and horizontal relations and contribute to theory in both areas.

Fourth, we examine human and social capital at both the individual and the collective levels of analysis. Many researchers have called for multilevel analytic studies (e.g., Oh, Chung & Labianca, 2004; Van Deth, 2003), but such research is, again, decidedly rare. Instead, although recognizing that both forms of capital can occur at multiple levels of analysis, scholars have largely conducted their empirical examinations at a single level, be it individual (e.g., Burt, 1997), work group (Oh, Labianca, & Chung, 2006), or organizational (Leana & Pil, 2006). Such studies, though informative in their own right, do not fully capture the complexity or the multilevel character of the constructs. In this study, we developed a multilevel theory that we empirically tested at both the individual and team levels of analysis. In essence, we argue that the combination of strong human capital at the individual level (teacher) and strong social capital at the group level (grade team) will result in the greatest improvements in student performance.

Finally, our research informs policy and practice. We apply theories of human and social capital—derived largely from the organizations and management literature—to address student performance in urban public schools. The findings from our research can provide direction to practitioners and policy makers regarding relative investments in each form of capital. As noted previously, human

capital has received far more attention and resources than social capital in public policy efforts to improve the quality of American schools. However, there is almost no comparative research to support this disproportionate focus on human capital. Our research tests the relative contributions of social capital and human capital to student achievement, and our findings can be used to guide future investments in each.

THEORETICAL FRAMEWORK

Human Capital and Performance

Since its introduction by Becker (1964) over 40 years ago, the concept of human capital has played a central role in models of individual and organizational performance. *Human capital* is defined as an individual's cumulative abilities, knowledge, and skills developed through formal and informal education and experience. Human capital can provide direct benefits in the form of superior performance, productivity, and career advancement. Further, it can lead to a "virtuous cycle" of improvement, as highly skilled workers find it easier to acquire new skills, further enhancing their performance leads (Becker, 1964; Wright, Dunford, & Snell, 2001). There is debate as to whether and how much human capital influences all dimensions of work performance, yet there is little disagreement about the positive effects of technical knowledge and skills on operational outcomes (Fisher & Govindarajan, 1992). And evidence exists even at the highest levels of management that human capital is related to correlates of individual performance, such as compensation and retention (Harris & Helfat, 1997; Phan & Lee, 1995).

The accumulated human capital held by a group of individuals in a workplace can also constitute a collective resource whose benefits accrue to work groups and organizations as a whole, as well as to the individuals embedded in them (Argote, 1999; Coff, 1999; Wellman & Frank, 2001). Although human capital and knowledge-related assets more generally are held by individual employees (Coff, 1999), individual knowledge is not independent from collective knowledge (Spender, 1996). Nahapiet and Ghoshal (1998) referred to the latter as *intellectual capital*, defined as the collective knowledge and knowing capability of organization members. From a team perspective, such knowledge is often conceptualized as the collective set of skills and knowledge that members bring to bear on team-related activities (Faraj & Sproull, 2000). Extensive evidence indicates that collective knowledge affects team performance and may yield important nonadditive benefits at that level (Faraj & Sproull, 2000; Moreland, Argote, & Krishnan, 1996; Smith, Collins, & Clark, 2005).

The impact of collective knowledge on the performance of individuals has received less attention in the literature (Day et al., 2005). However, the limited evidence suggests tangible benefits to those holding membership in high-ability groups. Tziner and Eden (1985), for example, found that team-level ability positively influenced supervisor ratings of individual member performance. Day et al. (2005) similarly found individual benefits accrued to members of high-ability teams.

We predict the same relationships will hold for individual and collective human capital and the performance of teachers in public schools. Human capital has played an important role in public policy debates regarding school reform and teacher effectiveness, with teacher certification, formal education, and other credentials playing a leading role in many models for improving schools (Cohen & Hill, 2001; Darling-Hammond, 2004). Thus, both organization theory and the direction of public policy suggest that teacher human capital should positively affect student performance outcomes.

Hypothesis 1. Teachers with higher levels of human capital demonstrate higher levels of performance.

Hypothesis 2. Teachers working in teams with higher levels of human capital demonstrate higher levels of performance.

At the same time, the content of knowledge, and its applicability to the task at hand, may have a more important influence on performance than does general human capital. Just as advanced training in accounting—regardless of whether it is at the master's or doctoral degree level—does not prepare one for a career teaching English literature to college students, the accumulation of years of education should not, beyond a certain threshold, be a strong predictor of how well one can teach mathematics in elementary school. Instead, we argue that for human capital to create value in school settings, it must be contextualized.

Gibbons and Waldman (2004) defined task-specific human capital as knowledge gained through "learning by doing" a particular set of tasks. In his study of technicians at work, Barley (1996) described what he called "particular knowledge," knowledge that is only relevant when it is put into practice in particular contexts and for particular types of problems. Similarly, Levinthal and Fichman (1988) found that in consulting firms, individual knowledge of specific client needs, rather than

generalized knowledge of their industry, was predictive of client retention. In the same way, we expected that teacher human capital specific to a setting and a task would have a more powerful effect on student achievement than would general human capital.

Hypothesis 3. Teacher human capital that is task-specific has a stronger effect on performance than does general human capital.

Horizontal Social Capital and Performance

Individual ties. Horizontal ties describe interactions among people who share group membership and/or occupy the same level in an organizational hierarchy. The concept of social capital captures both the structural relations among such individuals and the resources that can be mobilized through those relationships (Adler & Kwon, 2002; Bourdieu, 1986; Coleman, 1988). Such relationships are conduits for information, affection, and referrals that can lead to enhanced outcomes for individuals (Burt, 1997; Coleman, 1988), work groups (Oh et al., 2006), and organizations (Leana & Pil, 2006).

Horizontal ties can be described on several dimensions. First, having a greater *number* of ties helps employees obtain a broader range of perspectives (Dean & Brass, 1985). Second, individuals with more coworkers in their discussion networks have significantly higher income levels, according to Carroll and Teo (1996), who drew on data from the General Social Survey. This was especially true in the case of nonmanagers. Papa (1990) found that those employees most active in communicating at work made more and broader use of new technology introduced in their workplace, leading to concrete productivity gains.

Second, frequent interaction with others at work helps employees gather information quickly, thereby reducing environmental ambiguity and uncertainty. At the same time, close ties with others allow individuals to dispense with formality and self-censorship, and to get to the heart of issues and perhaps reveal vulnerabilities or weaknesses to colleagues (Carroll & Teo, 1996). Reagans and McEvily (2003), among others, have reported that frequent interactions and feelings of closeness tend to cooccur; that is, people tend to feel closer to people with whom they have frequent interactions. Thus, although these two aspects of interpersonal ties—frequency and closeness—may be separable conceptually, operationally they are often joined. In research, their combined effect is often referred to as the intensity or *strength* of ties (e.g., Hansen, 1999; Reagans & McEvily, 2003).

Research suggests that strong ties with coworkers (i.e., ties that are close and involve frequent interaction) can enhance individual performance (Papa, 1990; Roberts & O'Reilly, 1979). Meyerson (1994) found that Swedish managers with strong coworker ties earned higher wages, even after controlling for human capital differences (i.e., differences in education). In a study of claims adjusters, Papa (1990) reported that both the size of an individual's job network and the frequency and closeness of interactions within it had positive effects on productivity. Lazega (1999) found similar results for lawyers. Overall, such networks of relationships can be critical to individuals for effectively solving problems (see Orr, 1996) and especially helpful when there is a change in technology or work procedures (Cross, Borgatti, & Parker, 2002; Spender, 1996).

Team-level ties. At the team level, Coleman (1990) and others (Krackhardt, 1999; Kramer, Hanna, Su, & Wei, 2001) have suggested that "closure," which refers here to a dense network of relationships, leads to strong norms of reciprocity and reduces opportunistic behaviors. Closure in networks encourages the development of norms, generalized trust, identity, and cohesion, which in turn can enhance group effectiveness in achieving collective goals (Coleman, 1988; Nahapiet & Ghoshal, 1998; Putnam, 1993). In a recent meta-analysis, Balkundi and Harrison (2006) found that task performance could be higher in groups with dense ties.

Group-level social capital "is owned jointly by the parties to a relationship with no exclusive ownership rights for individuals" (Nahapiet & Ghoshal, 1998: 256). However, it does provide a resource that individuals can use for their own benefit and interests (Bourdieu, 1986; Coleman, 1990). Gabbay and Zuckerman (1998), for example, found that individual scientists benefit from high contact density in their units. Such benefits derive in part from the very goodwill that exists in the collective and from the resources and lower transaction costs that goodwill enables (Adler & Kwon, 2002). Podolny and Baron argued that closure benefits individuals in two ways: "(1) internalizing a clear and consistent set of expectations and values in order to be effective in one's role; and (2) developing the trust and support from others that is necessary to access certain crucial resources" (1997: 676).

With regard to teachers in public school settings, in an earlier work (Leana & Pil, 2006) we demonstrated the positive effects of teacher social capital on school-level indicators of performance. Bryk and Schneider (2002) similarly found that general trust—an indication of the quality of the relationships among teachers—was a significant predictor

of student performance within schools. Thus, we expected that the relationships between horizontal (i.e., within-group) ties and teacher performance would also be positive here.

The nature of these ties was also expected to be important. Specifically, performance should be enhanced in the presence of strong ties, when interaction among teachers is both frequent and close. When teachers interact with frequency, they are more likely to exchange information in a timely manner; when they also feel close to the other teachers with whom they interact, they should be more willing to reveal vulnerabilities and share sensitive information. This type of willingness is important to learning and development as it allows teachers to discuss their problems in the classroom and perhaps also their own professional shortcomings, rather than focus on more comfortable topics like their successes and professional strengths. In organizational contexts, Smith et al. (2005) showed that strong ties among organization members lead to superior organizational outcomes in technology firms, and the effects of tie strength are distinct from the number of direct contacts between those individuals.

Hypothesis 4. Teachers having (a) a greater number of ties and (b) stronger ties with others in their team demonstrate higher levels of performance.

Hypothesis 5. Teachers working in teams with (a) dense ties and (b) stronger ties among members demonstrate higher levels of performance.

Vertical Social Capital and Performance

Individual ties. Just as the number and quality of contacts an individual has within her/his work group are important, so is the quality of the relationship the individual has with her/his direct supervisor. Over 30 years ago, Graen and Cashman (1975) proposed that the same leader could show differences in the quality of interactions with individual subordinates ("vertical dyad linkages"). Moreover, these distinctions are reflected both in supervisor assessments and, more central to our study, supervisor and subordinate behaviors, such as the frequency of interaction between them. Subsequent research on what has come to be known as "leader-member exchange" has supported this basic premise and also shown that subordinates who have higher-quality exchanges with their supervisors generally perform better in their jobs. As Sparrowe and Liden stated, "The quality of the exchange relationship with the leader, which is based upon the degree of emotional support and exchange of valued resources, is pivotal in determining the member's fate within the organization" (1997: 522).

A more general argument has been made in the networks literature concerning the benefits to individuals of having ties with others in higher-status positions. Social resource theory suggests that exchanges with higher-status others should be particularly valuable to individuals because such ties hold resources like information and influence that they may not otherwise be able to access (Lin, 1999; Marsden & Hulbert, 1988). Cross and Cummings (2004) reported some support for the theory in an empirical study of knowledge workers. We propose that the quality of teachers' ties with the line administrators in their schools, who are typically the school principals but sometimes also assistant principals, should affect the teachers' performance.

Like the relations among teachers discussed earlier, tie strength, measured in terms of frequency and closeness, is an important aspect of teacher-administrator interaction. Indeed, the strength of a tie might be even more important in teacher-administrator relations because of the hierarchical differences between them—that is, teachers formally report to principals and assistant principals. With regard to frequency, teachers must talk to administrators with some regularity to gain timely information from them. If the teachers also feel close to the administrator(s), they are more likely to share information that might expose their professional challenges as well as strengths and thus open the door to learning about how to better address those challenges.

Team-level ties. The quality of a team's interactions with its leader can also affect both individual and team performance. An important dimension of social capital is the availability of conduits through which a group can access resources (Oh et al., 2004). Teams have connections to different categories of others, including members of similar teams, members of other functional groups, and contacts outside of their organization, as well as ties to the managers who directly supervise the teams' work (Hargadon & Sutton, 1997; Hinds & Kiesler, 1995). These ties are argued to be important for group effectiveness because they enable teams to access a broader pool of resources and exert greater organizational influence (Ancona & Caldwell, 1998; Burt, 1982; Tsai, 2001).

As stated above, a substantial body of research shows that the quality of leader-member exchange affects individual performance. The same logic can be applied at the team level. Managers in many organizations supervise multiple teams, and it is reasonable to expect that the quality of their inter-

actions with these teams will vary. Working in a team whose members have strong vertical ties should be beneficial to an individual, independent of his or her own interactions with the relevant leader. In the same way, teachers can derive secondary benefits if other members of their teams have strong ties with administrators, even if the teachers themselves do not have such ties.

Hypothesis 6. Teachers with stronger ties with school administrator(s) demonstrate higher levels of performance.

Hypothesis 7. Teachers working in teams having stronger ties with school administrator(s) demonstrate higher levels of performance.

Cross-Level Interactions: Team-Level Social Capital and Individual Human Capital

As previously described, social capital and human capital operate at multiple levels of analysis (Oh et al., 2004; Van Deth, 2004). They are also closely related. Studies of human capital have often emphasized not just individual skill and experience, but also factors that contribute to social capital, such as the sharing and exchange of information associated with skill development and application (Pil & Leana, 2000; Inkpen & Tsang, 2005; Wright et al., 2001). At the same time, building and leveraging human capital is subject to complex social processes as individuals share experiences, tell stories, and engage in other forms of knowledge exchange (Nahapiet & Ghoshal, 1998; Orr, 1996). Indeed, as Brown and Duguid (1991) demonstrated, complex learning often requires informal collaborations among employees in "communities of practice."

The social capital of a team can complement human capital "by affecting the conditions necessary for exchange and combination to occur" (Nahapiet & Ghoshal, 1998: 250), as well as by increasing the amount of information and resources that are flowing through it. Papa (1990) provided evidence that, even controlling for past performance, workers further improve their use of skills obtained in training through later communication with others. Dense networks enhance such information flow, as well as the trust that results in individuals' willingness to disclose weaknesses in their own knowledge bases (Baker, 1984; Coleman, 1988).

Tie strength can also affect how human capital is applied and diffused. Absorbing complex ideas from others often requires extensive interaction (Lane & Lubatkin, 1998), in part because interaction helps individuals refine their understanding of how knowledge is distributed (Weick & Roberts, 1993). Because complex knowledge can be difficult for an individual to obtain from others, it requires shared understandings and perceptions that emerge with high interaction (Polanyi, 1966). Furthermore, close ties increase the likelihood that exchange of such knowledge will occur (Ayas & Zeniuk, 2001; Sparrowe, Liden, Wayne, & Kraimer, 2001). Thus, as the issues under consideration become more complex and less scripted, the strength of relationships becomes more important (Hutchins, 1991; Moreland et al., 1996). In addition, the network of others that individuals draw upon can include not just strong direct ties but also indirect ties, which are ties through intermediaries (Granovetter, 1973). These indirect ties and connections are also conduits for knowledge transfer (Hansen, 1999; Tsai, 2001).

Human capital also facilitates the effective use of social capital for task performance. Having a strong personal knowledge base is important to an individual's seeking and using related know-how that is accessible both within and outside his or her team (Polanyi, 1966). Dense networks and/or strong ties have a potential disadvantage in that they may lead to exchanges that are comfortable but not necessarily useful for task performance (Mizruchi & Stearns, 2001). However, team members with higher skill should be better positioned to move beyond such comfortable exchanges to identify and access useful information originating from strong horizontal and vertical networks, in part because existing knowledge drives the search for new knowledge (Dosi, 1982). Further, they will be better able to modify and adapt such information to their particular needs. In these ways, the positive effects of an individual's human capital on performance should be stronger when he or she works in a team with strong horizontal and vertical social capital.

Hypothesis 8. Human and social capital interact in their effects on teacher performance in such a way that teachers having strong human capital who work in teams with strong (a) horizontal and (b) vertical ties demonstrate higher levels of performance.

METHODS

Sample and Procedures

In March 2004 we surveyed all classroom teachers in 202 elementary schools in a large urban school district in the northeastern United States. Surveys were distributed during teachers' paid professional development time by a teacher representative (usually the mathematics coach for the school) whom we had trained in survey distribu-

tion. Each survey was marked with a unique six-digit code so that individual teacher responses could be matched with student performance data. Data linking was done by a third-party "honest broker" to ensure the anonymity of individual teachers. After completion, the surveys were mailed back directly to the third party for data entry and matching to student achievement scores. Each teacher received a $10 gift card for participating in the study.

The current study was part of a larger research project we had undertaken; its primary objective was to examine how the school district scaled up a new mathematics curriculum in multiple schools. In this larger study, 199 schools participated (a response rate of 98.5%), and 5,205 out of 6,435 teachers returned identified surveys (a response rate of 80.9%). Standardized achievement tests were administered each May to all 3rd, 4th, and 5th grade students in the district. We obtained individual student math test scores from the school year preceding survey distribution (2003), as well as math scores from the focal school year (2004), so that we could assess the change in student achievement over the course of the year they spent with a particular teacher. Since only 4th and 5th grade students took the achievement tests in both 2003 and 2004, the relevant sample for our analysis was comprised of 4th and 5th grade teachers and the individual students they instructed in the 2004 school year.

The teachers in our sample were quite similar to teachers at other grade levels with a few exceptions: The 4th and 5th grade teachers had somewhat less experience teaching at their grade level than did teachers for the other grades (mean = 4.10 vs. 4.65),[1] and better scores on our assessment of their ability to teach math (mean = 5.5 vs. 4.3). They also had slightly fewer ties to other teachers in their grade (3.4 vs. 3.9).

Teachers were formally organized into grade-level teams (grade teams) in each school. Each team was charged with working collaboratively on curriculum planning and student assessment for its grade, and with enhancing and diffusing effective learning techniques. Teachers engaged in discussions of curricula and teaching methods, but task execution in the form of actual instruction was done independently by each teacher. To ensure that we were accurately capturing team social capital and related metrics, we restricted our sample to grade teams with at least three teacher respondents on all the social capital measures (the average grade team size in the final sample was 5.3 members; the average number of teacher respondents per grade team was 4.2). Restricting the sample in this way eliminated teams for which we did not have good representation of membership and thus provided a clearer picture of the actual—rather than selective—nature and strength of the social and human capital in each team (Oh et al., 2004; Sparrowe et al., 2001). There was the further advantage that the analytic tools we used could better discern differences between and within groups when there were more respondents within each group (Pollack, 1998). After these adjustments, the final sample encompassed 24,187 students, 1,013 teachers, and 239 grade teams.

Dependent Variable: Student Performance

As noted above, standardized achievement tests in mathematics and reading were administered each May to all 3rd, 4th, and 5th grade students in the district. Both the school district and the state scaled these test scores to permit comparability of students across grades and to understand growth in student achievement each year. Our analysis focused on 4th and 5th graders because these were the only students who had taken the standardized tests in the previous year (2003) and thus could provide a baseline from which to assess growth. Students in our sample had an average scale score of 662 on the mathematics portion of the test (s.d. = 35.5).

Predictor Variables: Human Capital

Teacher human capital. Human capital is generally conceptualized as having a formal educational component, as well as a more tacit, less codifiable element that is often gained through experience on the job (Becker, 1964; Nonaka, 1994). Formal education is believed to help individuals in a variety of ways, including providing them with access to new information, increasing their receptivity to new ideas, and enhancing their ability to monitor results (Boeker, 1997; Smith et al., 2005). Although in some contexts innate ability induces individuals to obtain more education (cf. Hambrick & Mason, 1984), in many school districts, including the one under study here, teachers are required to obtain a minimum number of continuing education credits each year. Furthermore, virtually all U.S. school districts reward teachers for attaining advanced degrees (Wayne & Youngs, 2003). We therefore included *formal education* as a measure of general human capital (1 = "bachelor's degree," 2 = "master's degree," 3 = "coursework beyond

[1] Detail on these metrics is provided below.

master's degree"). Distribution over these categories was good in our sample, with approximately 23 percent of the teachers holding bachelor's degrees, 39 percent holding master's degrees, and 38 percent having completed coursework beyond the master's degree.

The education literature suggests that for teachers, developing competency in the classroom may also be a function of experience and on-the-job development (McLaughlin & Talbert, 2001; Smylie & Hart, 1999). In school settings, expertise is often perceived as tacit in nature and heavily dependent on context. Teaching has elements of "craft learning," including pedagogical learner knowledge—the "pedagogical procedural information useful in enhancing learner-focused teaching in the dailiness of classroom action" (Grimmet & MacKinnon, 1992: 387)—and pedagogical content knowledge, which is related to material learned via formal instruction, yet is the product of teachers' reflection on practice over time (Shulman, 1987).

Interviews with teachers and school administrators suggested that teacher expertise is acquired through years of experience with students at the grade level being taught. We were also able to measure total experience in the field, and it was highly correlated with experience teaching at a particular grade level ($r = .62$). Furthermore, teachers pursued additional education as a matter of policy during their careers, leading to a high correlation between overall experience and formal education ($r = .51$). As a result, we used *years taught at grade level* as our second human capital metric. Our interview data suggested that beyond 5 years, the tacit learning that accrues from teaching at a particular grade levels off. This notion is in line with empirical findings (e.g., Rivkin, Hanushek, & Cain, 2005; Rosenholtz, 1985). Thus, we measured experience at grade level on the following eight-point scale: a code of 1 indicated teaching less than 1 year at the grade, and higher levels represented 1 year, 2 years, 3 years, 4 years, 5 years, 6–10 years, and 11+ years, respectively (mean = 4.1, or about 3 years of experience; s.d. = 2.3). The modal teacher had 3 years of experience, and less than a quarter of the sample (23.3%) reported more than 5 years of experience teaching at their current grade level.

Our third measure of human capital is task-specific in that it was an assessment of teachers' ability to teach mathematics. The school district under study had recently introduced a systemwide change in the mathematics curriculum centered on what education specialists have labeled "reform" or "constructivist" math (Ross, McDougall, Hogaboam-Gray, & LeSage, 2003). Teaching so-called reform mathematics entails a focus on developing children's higher-level mathematical reasoning, sometimes at the expense of basic facts and formulas. Practitioners and academics have strongly held, contradictory views about the usefulness and value of reform mathematics as an instructional model, in part because it places higher demands on teachers in terms of their understanding of how students learn. Such knowledge is inherently difficult to codify and is typically developed and transferred on-the-job (Polanyi, 1973; Reed & DeFillippi, 1990). Many elementary school teachers do not like to teach math and, indeed, the math specialists we interviewed described elementary school teachers as "math-phobes" and "scared of math." Moreover, we were told repeatedly that it takes extensive skill to understand how students comprehend and learn mathematics and to tailor math instruction to the challenges particular students face. Many teachers did not believe they had such ability.

To assess teachers' ability to teach mathematics, we used a subset of measures developed by the Learning Mathematics for Teaching (LMT) project at the University of Michigan (Hill, Schilling, & Ball, 2004). The LMT has developed a series of questions geared specifically to gauging the levels and growth in teacher knowledge and understanding of how students learn mathematics. The LMT researchers have provided extensive evidence regarding the validity of the items (Hill, Rowan, & Ball, 2005; Hill et al., 2004). Figure 1 shows an example (released item).

From the full battery, we selected 12 items assessing teachers' ability to interpret student mathematical thinking. To ensure content validity, we selected items that mapped onto the 2004 National Council for Teachers of Mathematics recommended subject matter for K–5 students. The ability test we used is thus an indicator of teacher knowledge regarding the specific task demands associated with math *instruction* rather than abstract mathematical knowledge. We pretested the items on over 100 teacher coaches, half of whom specialized in math and half, in literacy. We found that the math coaches performed significantly better, getting almost 60 percent of the items correct versus 31 percent for the literacy coaches. The average score on this assessment for our sample was 45 percent (i.e., on average, teachers correctly answered approximately 5.5 of the 12 questions).

Team human capital. Human capital is socially embedded. Although there has been mixed reaction to measuring collective knowledge as the aggregation of individual knowledge or ability (Nahapiet & Ghoshal, 1998), collective human capital is often conceptualized as the sum of individual expertise (Barrick, Stewart, Neubert, & Mount, 1998; Chan,

FIGURE 1
Math Assessment Sample Item[a]

Takeem's teacher asks him to make a drawing to compare $\frac{3}{4}$ and $\frac{5}{6}$. He draws the following:

and claims that $\frac{3}{4}$ and $\frac{5}{6}$ are the same amount. What is the most likely explanation for Takeem's answer? (Mark ONE answer.)

a) Takeem is noticing that each figure leaves one square unshaded.

b) Takeem has not yet learned the procedure for finding common denominators.

c) Takeem is adding 2 to both the numerator and denominator of $\frac{3}{4}$, and he sees that that equals $\frac{5}{6}$.

d) All of the above are equally likely.

[a] Source: *Learning Mathematics for Teaching* (Hill, Schilling, & Ball, 2004).

1998; DeShon, Kozlowski, Schmidt, Milner, & Wiechmann, 2004). We followed this precedent, but because team sizes varied somewhat, we used the average to represent the stock of human capital in a grade team rather than the sum of individual experience and ability. Teams with better educated, more experienced, and higher-ability members thus had higher team human capital scores. Aggregated experience and ability in this form follows from the literature in economics, which would label this average a team's "intellectual infrastructure" (Huang, 2003).

Predictor Variables: Social Capital

Teacher social capital: Number and strength of horizontal ties. In our surveys, teachers were asked about the number of ties, frequency of interaction, and felt closeness with other teachers at their grade level (horizontal ties). Not all interactions at work are goal directed, and ties can be classified as serving different purposes (Podolny & Baron, 1997). Following Sparrowe et al. (2001) and Reagans and Zuckerman (2001), we focused specifically on instrumental or task-oriented ties. Such ties are particularly beneficial in complex environments such as schools (Harrington, 2001). Furthermore, because research in the education sector suggests that teachers draw on different advice networks for different subject areas (Spillane, 1999; Spillane, Hallett, & Diamond, 2003), we asked teachers to describe whom they talked to about *math* instruction. We found that the average teacher reported talking with approximately three other teachers in their grade team about mathematics over the month prior to the survey.

We developed a second indicator of social capital, the *strength* of interactions a teacher had with team members. The literature provides different approaches to estimating the strength of relationships at work. Studies have used the product of frequency and closeness (e.g., Reagans & McEvily, 2002), either frequency or closeness alone (e.g., Reagans 2005), or averages of the indicators of tie strength (e.g., Collins & Clark, 2003; Hansen, 1999). Here, we calculated an index of tie strength by averaging the frequency with which a focal teacher exchanged information about mathematics with other teachers in the grade team and the teacher's reported closeness to those contacts. We measured closeness via teachers' self reports (1 = "not at all close," to 5 = "very close") and measured frequency as the number of times the focal teachers reported talking to grade-level peers about math instruction during the last month. We rescaled the frequency measure so that it would have an input commensurate with teacher closeness ("0–5" = 1, "6–10" = 2, "11–15" = 3, "16–20" = 4, and "21+" = 5). Horizontal tie strength was the average of these two measures, and thus scores ranged from 1 (low) to 5 (high). The mean rating for our sample was 2.75 (s.d. = 1.06).

It could be argued that the potential impact of social capital on performance occurs when both

frequency and closeness are high, and that one amplifies the other. For example, frequent conversations about work between employees who are not close are likely to be guarded and, whenever possible, superficial. At the same time, infrequent conversations, even among coworkers who feel close to one another, are not likely to have much effect on performance. To capture this situation, some researchers have chosen to use the product of frequency and closeness in their assessment of relationships (cf. Reagans & McEvily, 2002). Although recognizing concerns that have been raised regarding the use of product terms (cf. Evans, 1991), we ran all analyses using the product of frequency and closeness as an alternative indicator of tie strength. We found no substantive difference in results.

Teacher social capital: Strength of vertical ties. We followed the same approach in our assessment of vertical tie strength. This index averaged the frequency with which a focal teacher exchanged information about mathematics with school administrator(s)—typically the school principal—in the month preceding data collection, and the teacher's reported closeness to the administrator(s) (1 = "not at all close," to 5 = "very close"). As with our measure of horizontal tie strength, we rescaled the frequency component so that it would have an input commensurate with administrator closeness in the strength metric ("0–1" = 1, "2" = 2, "3" = 3, "4" = 4, "5+" = 5). The range of vertical tie strength was thus 1–5, and the mean score for our sample was 2.2 (s.d. = 1.3). As with horizontal ties, we reran all analyses using the product of frequency and closeness as our measure of vertical tie strength. Again, we found no substantive differences in results.

Team social capital: Density and strength of horizontal ties. According to Adler and Kwon (2002), definitions of social capital differ across levels of analysis on the basis of the relations an actor maintains with other actors, the structure of relations among actors within a collectivity, or both types of linkages. Information exchange associated with group-level social capital is closely related to the information linkages maintained by individual group members. As Brass and colleagues noted, "When two individuals interact, they not only represent an interpersonal tie, but they also represent the groups of which they are members" (Brass, Galaskiewicz, Henrich, & Tsai, 2004: 801). We approached our measurement of social capital at the team level with this in mind. Communication in teams is the outcome of dyadic exchange and can be assessed from a direct aggregation of such exchanges. Individual social ties and communication ultimately define higher-level forms of social capital (Leana & Van Buren, 1999), and density is an established metric of the resulting cohesion of a network (Borgatti, 1997).

Following Degenne and Forse (1999), we measured team density by calculating the total number of ties (interactions about mathematics) among all teachers in the same grade-level team divided by the theoretical maximum number of such ties among teachers in the team. Team density could take on values between 0 and 1, with 0 meaning that none of the teachers on a team talked with other members of the team about math instruction, and 1 meaning that each teacher in the team talked to every other member about math instruction. The average team density was .64. We also calculated a team-level measure of the strength of horizontal ties, basing it on our individual measure previously described. To control for team size, we measured tie strength as the average of individual-level strength scores (frequency of interaction about math instruction with other team members averaged with reported closeness).

Team social capital: Strength of vertical ties. We based a team-level measure of the strength of vertical ties on the previously described individual index (frequency of interactions about math instruction that teachers had with school administrators averaged with teachers' reports on closeness to those administrators). To control for team size, we used an average of the individual members' vertical strength scores for each team.

Control Variables

Score on prior year's achievement test. We controlled for a student's performance on the standardized math achievement test administered in May 2003 (mean = 637.1, s.d. = 39.7). As such, we were effectively measuring change in a student's performance in 2004 that was directly attributable to the student's experience with a focal teacher and grade team in the year of the study. This value also served as a control for school-level effects on student achievement, since these are captured in the students' 2003 scores.

Other student-level controls. We did not expect student circumstances to change dramatically from one year to the next, yet some factors might affect the *rate of growth* in student achievement over the course of a year. Thus, we controlled for student *grade level* (4th grade vs. 5th grade) as well as *special education status.* Approximately 7 percent of the students in our sample were enrolled in some sort of special education instruction. We further controlled for *attendance* (the number of days a focal student attended school), and the *socioeco-*

nomic status (SES) of each student. In measuring SES, we followed the standard approach in education research, distinguishing students who qualified for federally subsidized free or reduced-cost lunches from those who did not. Such lunch subsidies are based on family income. We used two dummy variable to capture SES. The first was set at 1 if students received free lunch, and the second was set at 1 if students received a reduced-cost lunch. The default category for this variable was students who paid the full lunch rate. In total, over half the students in our sample received free or reduced-cost lunch, with approximately 46 percent receiving free lunch and an additional 7 percent receiving reduced-cost lunch.

RESULTS

Table 1 summarizes the descriptive statistics. The correlation calculations were all performed at the teacher level (e.g., student scores are averaged for each teacher, and grade-level scores are assigned to the teacher). In the analyses reported below, however, these were modeled at the appropriate levels of analysis.

As might be expected, the strongest correlation for the dependent variable (student math score in 2004) is the prior year's score. Low SES and special education status are negatively related to student achievement, and school attendance is positively correlated with student achievement. At the teacher level, formal education, experience, and ability, as well as both horizontal and vertical tie strength, are positively and significantly correlated with student performance. At the grade-team level, all human capital indicators (formal education, experience, and ability) and all indicators of social capital (density and horizontal and vertical tie strength) are positively and significantly related to performance. As might be expected, teacher-level metrics of human and social capital are highly correlated with their corresponding grade-level metrics.

Since our data were nested, we were able to test our hypothesized relationships within and between those nested entities. We used hierarchical linear modeling (HLM) because of its capacity to model and statistically evaluate structural relations in nested data (Raudenbush, Bryk, Cheong, & Congdon, 2004). In particular, HLM permitted us to simultaneously explore individual and team-level relationships while correcting for the standard errors at each level. The resultant multilevel model addressed and accounted for the fact that individuals and groups were not separate conceptually or empirically and had cross-level influences on one another (Lindsley, Brass, & Thomas, 1995).

We modeled the impact of human and social capital on performance with a three-level nested data structure. Students were assigned to (i.e., nested in) teachers, who were in turn assigned to particular grades—i.e., nested in grade teams. There were three associated submodels. At each level, we model the structural relations at that level, as well as residual variability at that level. In its simplest form, the model is as follows:

$$\text{Level 1: } Y_{ijk} = \pi_{0jk} + \sum_{p=1}^{p} \pi_{pjk} a_{pjk} + e_{ijk}.$$

$$\text{Level 2: } \pi_{pjk} = \beta_{pok} + \sum_{q=1}^{Q_p} \beta_{pqk} X_{QJK} + r_{pjk}.$$

$$\text{Level 3: } \beta_{pqk} = Y_{pq0} + \sum_{s=1}^{S_{pq}} Y_{pqs} W_{SK} + u_{pqk}.$$

In these analyses, we were examining outcomes for student cases *i* nested within teachers *j* in grade teams *k.* The level 1 coefficients are represented by π_{pjk}. These become an outcome variable in the level 2 model, where β_{pqk} are the level 2 coefficients. These in turn become an outcome variable in the level 3 model, where Y_{pqs} are the level 3 coefficients.

We first undertook an unconditional analysis, dividing the total variance across the three levels. This initial analysis suggested that the variance across the levels was broken down as follows: student level, 62.4 percent; teacher level, 26.7 percent; and team level, 10.9 percent.

The results of our hierarchical linear modeling are reported in Table 2. For ease of reading, we report these results in the format conventionally used to describe regression results, listing first the base model at the student level, and then adding in additional explanatory variables at the other levels of analysis.

Model 1 reflects the impact of all the student-level controls on student achievement. These were entered at the student level of analysis. The average increase in student score during the year under study was approximately 25 points. As expected, student performance in 2003 was a strong predictor of performance in 2004. Also, 4th grade growth in math achievement was significantly higher than achievement growth in 5th grade. We found that special needs students had significantly lower growth during the year under study, as did students from the lowest SES group (and both groups were starting from lower scores to begin with). Atten-

TABLE 1
Descriptive Statistics and Correlations

Variables[a]	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Score in 2004	661.8	35.5																		
2. Score in 2003	637.1	39.7	.74**																	
3. Special education status	7%		−.31**	−.22**																
4. Fourth grade	54%		−.09**	−.65**	−.04															
5. Attendance	169.4	11.3	.56**	.38**	−.14**	.08**														
6. SES: Free lunch	46%		−.32**	−.27**	.04	.03	−.19**													
7. SES: Reduced lunch	7%		.18**	.17**	.00	−.02	.18**	.15**												
8. Formal education	2.2	.77	.21**	.16**	−.03	−.01	.11**	−.17**	.06*											
9. Teacher experience	4.1	2.27	.26**	.22**	−.07*	−.05	.18**	−.14**	.03	.39**										
10. Teacher ability	5.5	2.40	.08**	.01	.03	.07*	.07*	.00	.08**	−.01	−.08*									
11. Horizontal ties	3.35	1.97	.04	−.03	−.02	.05	.05	−.01	.06	.00	.03	.05								
12. Horizontal strength	2.75	1.06	.14**	.06	−.02	.05	.09**	−.03	.14**	.00	.06	.10*	.47**							
13. Vertical strength	2.19	1.27	.10*	.00	−.03	.08**	.05	.08**	.07*	.06	.07*	.06*	.20**	.32**						
14. Team density	.64	.21	.13**	.06*	.05	.03	.02	.05	.15**	.02	.03	.07*	.41**	.41**	.22**					
15. Team horizontal strength	2.77	.74	.20**	.09**	.01	.07*	.12**	−.05	.18**	.04	.04	.11**	.31**	.67**	.23**	.61**				
16. Team vertical strength	2.22	1.04	.06	−.06	−.04	.12**	−.01	.13**	.08**	.02	.04	.07*	.11**	.23**	.66**	.33**	.34*			
17. Team formal education	2.2	.44	.23**	.18**	.02	−.02	.13**	−.26**	.08**	.57**	.28**	.00	−.02	.04	.02	.04	.06	.03		
18. Team experience	4.2	1.26	.22**	.21**	.01	−.08**	.11**	−.21**	.05	.28**	.54**	−.02	−.01	.04	.04	.03	.06*	.06*	.50**	
19. Team ability	5.5	1.40	.10**	.00	.01	.12**	.09**	.01	.12**	.01	−.02	.56**	.03	.14**	.08*	.13**	.20**	.12*	.02	−.02

[a] "SES" is socioeconomic status.
* $p \leq .05$.
** $p \leq .01$.

TABLE 2
Results of HLM Analyses Predicting Student Performance in 2004[a]

Variables	Model 1		Model 2		Model 3		Model 4		Model 5	
Intercept γ_{000}	661.56***	0.46	661.50***	.45	661.56***	0.47	661.58***	0.43	661.58***	0.43
Level 1: Students										
Score in 2003 γ_{100}	0.69***	0.00	0.69***	0.00	0.69***	0.00	0.69***	0.00	0.69***	0.00
Special education status γ_{200}	−7.68***	0.55	−7.69***	0.55	−7.69***	0.55	−7.73***	0.55	−7.71***	0.55
Grade 4 γ_{300}	22.44***	0.93	22.23***	0.90	22.38***	0.93	21.96***	0.88	21.93***	0.88
Days attended γ_{400}	0.18***	0.01	0.18***	0.01	0.18***	0.01	0.18***	0.01	0.18***	0.01
SES: Free lunch γ_{500}	−1.92***	0.36	−1.90***	0.36	−1.90***	0.36	−1.87***	0.36	−1.88	0.36
SES: Reduced lunch γ_{600}	0.12	0.60	0.12	0.60	0.13	0.60	0.09	0.60	0.09	0.60
Level 2: Teachers			*Teacher variables grand-mean-centered*		*Teacher variables centered at group level*					
Human capital										
Formal education γ_{010}			0.61	0.41	0.14	0.44	0.14	0.44	0.30	0.45
Experience at grade γ_{020}			0.62***	0.14	0.64***	0.15	0.64***	0.15	0.64***	0.15
Ability to teach math γ_{030}			0.25*	0.12	0.23∼	0.13	0.23∼	0.13	0.20	0.13
Social capital										
Horizontal number γ_{040}			0.004	0.13	0.06	0.14	0.06	0.14	0.07	0.14
Horizontal strength γ_{050}			0.24	0.33	−0.44	0.37	−0.44	0.37	−0.45	0.37
Vertical strength γ_{060}			0.78***	0.26	0.74*	0.29	0.73*	0.29	0.72*	0.29
Level 3: Grade team										
Team social capital										
Density γ_{001}							1.93	2.58	1.94	2.58
Horizontal strength γ_{002}							1.91*	0.77	1.91*	0.77
Vertical strength γ_{003}							0.96∼	0.55	0.96∼	0.55
Team human capital										
Formal education γ_{004}							3.08***	1.13	3.08***	1.13
Experience at grade γ_{005}							0.37	0.40	0.36	0.40
Ability to teach math γ_{006}							0.29	0.32	0.29	0.32
Cross-level interactions										
Team density × teacher formal education γ_{011}									0.36	2.57
Team horizontal strength × teacher education γ_{012}									−0.56	0.83
Team vertical strength × teacher education γ_{013}									0.91	0.57
Team density × teacher experience γ_{021}									0.73	0.88
Team horizontal strength × teacher experience γ_{022}									0.21	0.29
Team vertical strength × teacher experience γ_{023}									−0.30	0.20
Team density × teacher ability γ_{031}									−1.52*	0.78
Team horizontal strength × teacher ability γ_{032}									0.58*	0.24
Team vertical strength × teacher ability γ_{033}									−0.08	0.17
Deviance	216,340.94		216,291.87 Compared to model 1:		216,308.99 Compared to model 1:		216,269.03 Compared to model 3:		261,257.39 Compared to model 4:	
df			6		6		6		9	
χ^2			49.06***		31.94***		39.96***		11.65	

[a] Values are HLM coefficients and corresponding standard errors.
* $p \leq .05$
** $p \leq .01$

dance at school significantly enhanced student growth in math achievement.

In model 2, we added teacher covariates, which were centered at the grand mean. In terms of interpretation of the results, this means that in model 2, teacher-level covariates are assessments of how a focal teacher's levels of human and social capital impact change in student achievement *relative* to the level of capital possessed by *all teachers* in the sample. We found strong support for the effects of

teacher human capital on student achievement gains. As expected, we did not find a significant relationship between formal education and student attainment. However, teacher experience at grade level as well as math teaching ability were significantly and positively associated with growth in students' achievement in math. Thus, Hypotheses 1 and 3 were supported. For the social capital measures (number and strength of ties), the horizontal indicators were not significant predictors of growth in student achievement. Thus, we did not find support for Hypothesis 4. The strength of teachers' vertical ties, however, was positively and significantly related to growth in student performance, supporting Hypothesis 6.

As a next step, in model 3 we centered teacher covariates at their group means. Although some debate has occurred in this area (e.g., Snijders & Bosker, 1999), Raudenbush and Bryk (2002) recommended group centering when covariates are entered at more than one level of analysis to properly estimate the slope variance. One of the reasons for their recommendation is that the estimates may be unreliable because the grand mean may be unrealistic for some of the group-level units.[2] What this means in terms of interpretation of the results is that in model 3, the teacher-level covariates were assessments of how a focal teacher's levels of human and social capital influenced student achievement *relative* to the level of capital possessed by *colleagues in the same grade team.* When treating data as compositional in this way, we found that the students of more experienced teachers showed significantly higher growth in performance. Higher teacher ability was also a positive predictor of growth, albeit of marginal statistical significance. As in model 2, formal education and the number and strength of horizontal ties had no significant relationship with students' performance gains. However, vertical tie strength (i.e., ties with school administrators) was a significant predictor of growth in student math scores. Both models 2 and 3 represent better fits to the data than model 1.

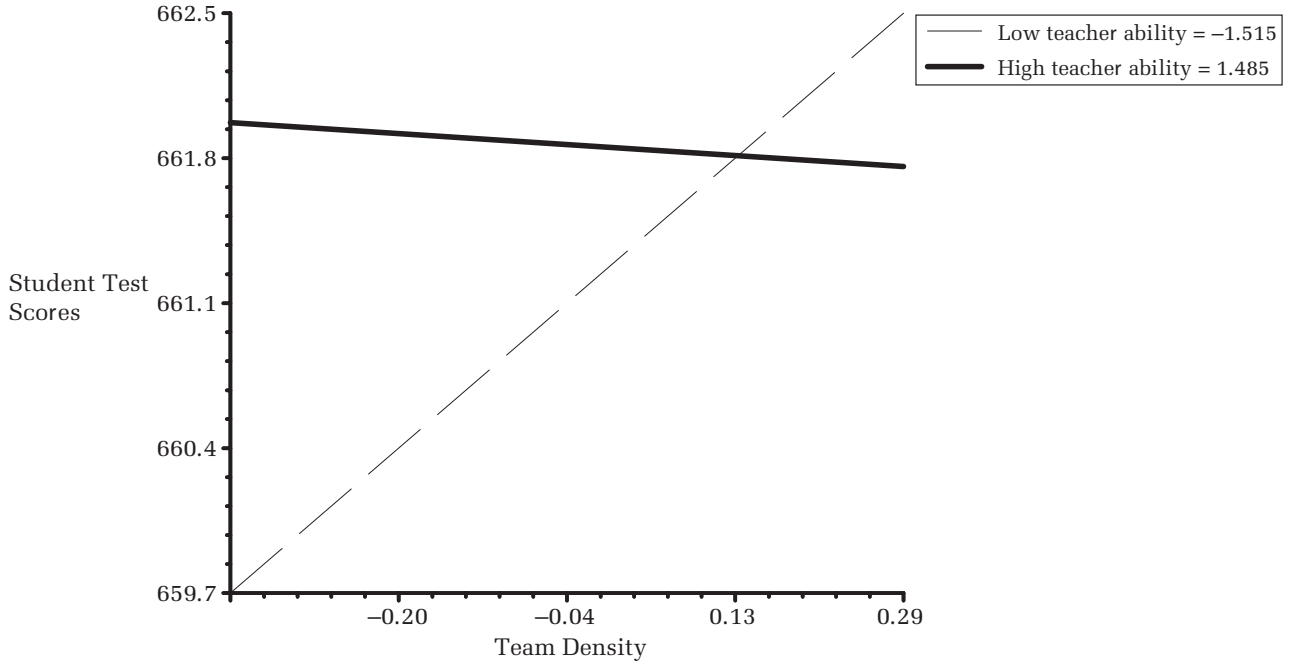
In model 4 we added team-level covariates to the variables from model 3. Here, the average formal education attainment of team members had a significant and positive influence on growth in student performance, but there was no significant relationship between either team experience or teaching ability and student achievement growth. Thus, Hypothesis 2 was supported but, at the team level, Hypothesis 3 was not. With respect to horizontal social capital, team horizontal tie strength was a significant predictor of student achievement, offering partial support for Hypothesis 5. Team vertical tie strength had a positive effect (albeit of marginal statistical significance) on student achievement growth, providing some support for Hypothesis 7. Model 4, which incorporated grade-level covariates, had significantly better explanatory power than model 3, which contained only student- and teacher-level covariates.

In examining the standardized effects for the significant relationships at the team level, we found that a one standard deviation increase in team horizontal tie strength was associated with a 5.7 percent gain in student achievement. A similar change in team-level educational attainment led to a 5.5 percent gain. At the teacher level, a one standard deviation increase in vertical tie strength was associated with a 3.7 percent gain in student math achievement, and a similar increase in tenure was associated with a 5.9 percent gain. A one standard deviation increase in teacher ability was associated with a 2.2 percent gain in student achievement.

As a final test, we explored the cross-level effects on performance of social capital at the team level and human capital at the individual level. Such cross-level interactions exemplify "frog-pond" effects, whereby team context can affect the influence of individual characteristics on performance outcomes (House, Rousseau, & Thomas-Hunt, 1995). Here, we found that teacher human capital (ability) and team social capital (horizontal density and tie strength) together affected student achievement (model 5). Figures 2 and 3 show the form of these relationships. The first item of note in both figures is that low-ability teachers derived some benefit from social capital in teams with both intense and dense communications. High-ability teachers, in contrast, obtained little benefit, and they might even incur some cost in dense teams. Second, teacher ability played a role in the benefits derived from different types of social capital. When social capital was operationalized as the strength of ties among team members, more-able teachers were the primary beneficiaries. This finding supports Hypothesis 8 and, as we have argued, the benefit found may be a result of these teachers' enhanced capacity to integrate and use the new information that is generated through frequent and frank conversations about their work. When social capital

[2] For example, in the case of grade teams and experience, it is possible that mean experience across all grade teams can have a value much higher or lower than the mean experience for a particular grade team. In that situation, it is possible that no teachers in that grade team even have the level of experience specified by the grand mean. This situation can lead to unreliable estimates in the same way that specifying an "unrealistic" intercept would.

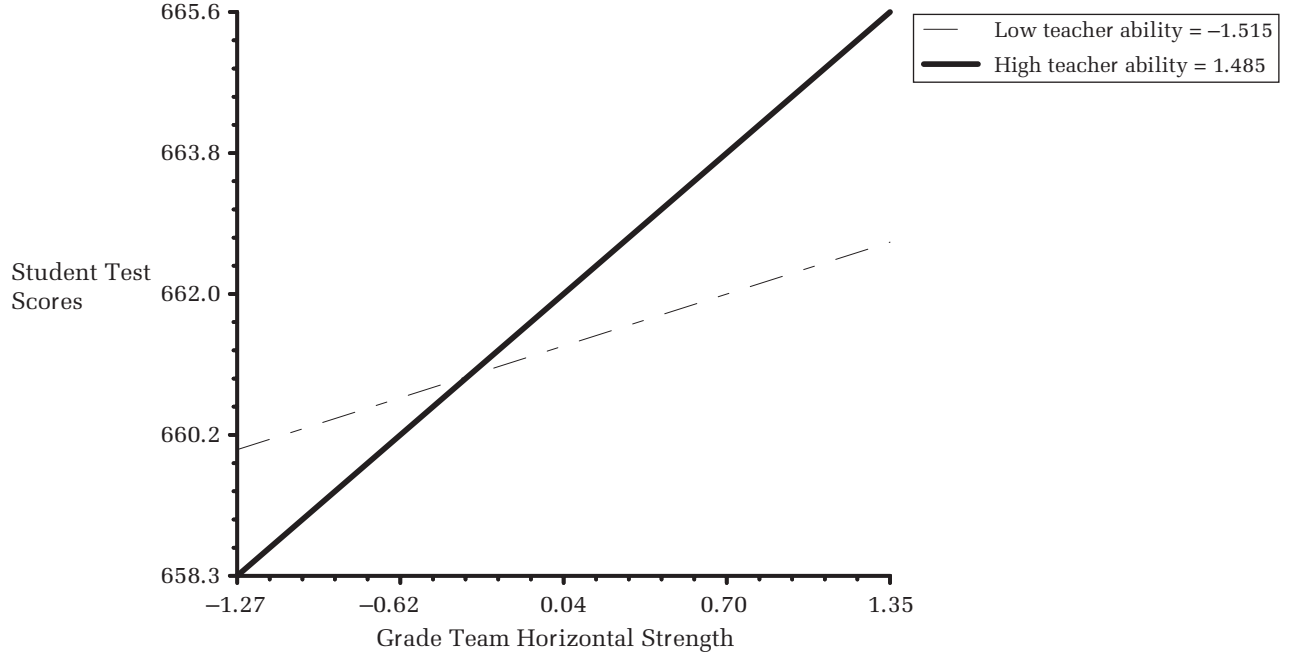
FIGURE 2
Cross-Level Effects: Teacher Ability (25 & 75%) × Team Density (5–95%)



was operationalized as network density, however, we found that less-able teachers benefited most. This unexpected finding may be a result of the more extensive information flow and generalized trust entailed in closed networks (Coleman, 1990).

Our cross-level effects are substantive ones. An increase in team density of one standard deviation was associated with a 2.8 percent gain for low-ability teachers. At the same time, a one standard deviation increase in the strength of team ties was associated with a 7.4 percent increase in student achievement gains for high-ability teachers.

FIGURE 3
Cross-Level Effects: Teacher Ability (25 & 75%) × Team Horizontal Strength (5–95%)



Overall, model 5 explains a sizable portion of the variance at each level of analysis. In relation to a multilevel model with no covariates, our final model explains 47 percent of the variance in student achievement growth residing at the student level. It explains 85.7 percent of the variance that resides at the teacher level and 80.4 percent of that at the team level. These results come with a caveat, however, in that the chi-square test shows that model 5, which includes the cross-level interactions, was not a better fit to the data than model 4, which does not include the cross-level interactions. Although horizontal tie strength and density show a significant interaction with teacher ability, they are the only two significant interactions out of nine cross-level interaction tested between forms of team social capital and individual human capital. At the same time, significant interactions are often difficult to detect in field studies (see McClelland and Judd [1993] for an in-depth discussion of this point), and our results offer some indication that cross-level interactions between social and human capital are at work in these settings.

DISCUSSION

We developed and tested a model of human and social capital that assessed their individual- and group-level effects on performance. Both forms of capital have received extensive attention in the literature, yet efforts to examine their joint effects are few. Furthermore, despite calls from theorists for multilevel studies of their effects (Oh et al., 2004; Van Deth, 2003), empirical multilevel work examining these constructs is decidedly rare. Our research, in contrast, captured the complex nature of these phenomena operating at multiple levels within organizations. Consequently, we were able to uncover relationships that may be missed in research conducted at a single level of analysis, or with only one form of capital. In addition, in our research we were able to leverage a context in which the measure of performance scales across levels of analysis, with a sufficiently large nested sample to be able to test its within-level and cross-level relationships.

Contributions to Theory and Research

We found several results of interest to theory and research. First, in support of human capital theory, we saw important benefits to students derived from the human capital of their teachers (Becker, 1964; Fisher & Govindarajan, 1992). At the individual level, teacher human capital that was specific to setting (years teaching in grade) and task (ability to teach math) had a positive effect on student performance, but teacher educational attainment did not. At the same time, we did find that higher levels of formal education at the team level were positively associated with student performance gains. This finding suggests that working with highly educated others yields spillover benefits to individual teachers and their students, regardless of the individual teachers' own levels of education.

Second, our study contributes to theory and research on social capital by jointly examining horizontal and vertical linkages. We found that strong horizontal relations were very important at the group level—that is, when teachers were in teams with strong group ties, their students performed better. As argued previously, such strong relations should facilitate rich exchange and enhance the availability and flow of resources and ideas. Vertical tie strength, in contrast, seems to provide benefits primarily at the individual level (that is, in relations between administrators and individual teachers). We found that students whose teachers had strong ties to school administrators showed higher growth in math achievement. Such effects were not found at the team level.

A third and related point concerns the cost of social capital. For example, a potential drawback of strong group ties is that a group may become too insular and not receptive to external information or ideas (Hansen, Mors, & Lovas, 2005). However, in this context, extensive input and interaction with others outside a team may not be necessary or even desirable in terms of student performance. As we have shown, teaching math to students at one grade level is different from teaching math to students at another grade level. Thus, the most useful advice on teaching may come from one's own grade-level team. Moreover, teachers' work in elementary schools involves primarily what March (1991) labeled "knowledge exploitation" rather than "knowledge exploration." In such a context, team insularity may not represent much of a threat to performance (see Hansen et al. [2005] for work in this vein). This argument stresses the important issue of boundary conditions in specifying the effects of social capital.

Finally, beyond looking at how constructs behave across levels of analysis, this cross-level research also allowed us to examine cross-level interactions. In that regard, students of high-ability teachers who were also nested in groups with strong ties performed significantly better. This finding supports our prediction regarding cross-level interactions (Hypothesis 8) and suggests that more-able teachers are better prepared to utilize the

advantages that may come from strong ties among their peers.

At the same time, less-able teachers appeared to benefit most from network density. According to Coleman (1988, 1990) and others (e.g., Baker, 1984), network density (or the degree of closure within a group) is beneficial for two primary reasons. First, closure enhances information access and diffusion within the group. Thus, if all 4th grade teachers are talking to one another about teaching mathematics (ties are dense), there should be wide diffusion of any one individual teacher's ideas and experiences in the classroom. In this way, less-able teachers will become aware of the teaching practices of their more-able peers. Second, closure enhances trust—or the willingness to be vulnerable to others in the group (Rousseau et al., 1998). Recall that this was a primary argument underlying our statements regarding density (Hypothesis 4). When teachers trust one another, they are more likely to reveal their weaknesses and perhaps address them using the support and guidance of their peers. In future research, these findings may generalize to other knowledge workers as well.

Contributions to Policy and Practice

The education literature distinguishes between a bureaucratic conceptualization of education and a professional view (Firestone & Bader, 1991). In the former, the emphasis is on standardization, structured curricula, and output control via testing. In the latter, "judgment and trial-and-error learning must supplement a rich, complex knowledge base" (Firestone & Bader, 1991: 71). The professional view requires interaction among teachers; the bureaucratic view does not. Traditionally, public policy has been driven by the assumptions of the bureaucratic "standards-based accountability model" (Linn, 2000). Our findings suggest, however, that the importance of exchange between teachers, and teachers and principals, should not be underestimated. This does not mean abandoning all elements of the bureaucratic model. For example, structured curricula and standardized instructional practices may provide a common reference point and baseline for productive exchange. However, our results, combined with those reported in other recent large-scale studies (Bryk & Schneider, 2002; Leana & Pil, 2006), suggest that policy makers may wish to broaden their sights to consider incentives and mandates that foster social capital in schools. Tools to accomplish this can range from scheduling daily grade-level meetings and providing faculty gathering areas, to collective grade-level training, reward structures based on grade-team performance, and the like. Although some of these may be taken for granted in other industries, it is important to stress that they are still the exception rather than the rule in public schools (cf. Kochanek, 2005).

The focus on teacher human capital as a lever for enhancing student outcomes has been dominant in policy circles for some time (Darling-Hammond & Younds, 2002). Indeed, in most school systems, formal educational attainment and general teaching experience are tightly linked with salary (Murnane, 2008). Our findings question such a practice. Instead, we find that teachers' human capital must be specific to their setting (experience teaching at grade level) and their task (ability to teach math) to yield benefits for students in the form of achievement gains. The implication is that employment practices that promote stability in teacher assignments in particular schools, along with professional development that is specific to the subject matter, may be better investments by school districts than is the current focus on general educational attainment.

This discussion brings us to a broader point regarding the role of formal education: As in many organizational contexts, the evidence linking formal education to teacher performance is limited and mixed (Hartcollis, 2005). Some researchers have found evidence that student performance is enhanced when a teacher holds a master's degree (Betts, Zau, & Rice, 2003), but other studies have yielded no such evidence (Clotfelter, Ladd, & Vigdor, 2006; Rivkin et al., 2005). Despite this mixed support, there is little agreement in education circles on an alternative measure of quality, which encourages a tendency to fall back on a readily available (if flawed) indicator of human capital, formal education (Rockoff, 2004).

Our results suggest that doing so is a mistake. Formal education, though an easy metric to collect, often has limited bearing on the direct performance of individuals because of the tacit and often organization-specific character of know-how that is required to attain superior outcomes. In schools, we find that the contextually specific metrics of human capital are good predictors of employee performance. For example, our measure of teacher experience is both situationally specific (i.e., experience teaching at grade level) and a significant predictor of performance for individual teachers, and our measure of teacher education (i.e., highest degree attained) is a general one and not significantly related to performance. This finding is consistent with observations in prior research that tenure in a particular job may be a better predictor of performance than a less-specific measure like com-

pany tenure (cf. Hunter & Thatcher, 2007). We also find that our contextualized measure of teacher ability (i.e., ability to teach mathematics) is associated with positive student outcomes. Together, these findings highlight the need for researchers and practitioners alike to move beyond easily obtained metrics such as formal education to also consider context- and task-specific measures in their models of employee human capital and performance. For policy makers, our finding suggests that they may fruitfully look beyond educational attainment in their assessments of teacher preparation or quality.

Our findings regarding vertical ties in schools may also have important implications for policy makers and school practitioners. We find that the students of teachers who report strong ties to school administrators show higher growth in math achievement. However, the underlying dynamics driving these effects are not well understood. As with much of the older management research on leader-subordinate relations, in the education literature any attention to such relationships in schools has tended to focus on principals and their leadership styles rather than on the interaction between principals and teachers. It is possible that principals seek advice from the stronger teachers in a school, rather than the reverse. Efforts to involve teachers in this manner can lead to enhanced trust between teachers and administration (Kochanek, 2005). In addition, relatively simple matters, like the span of control of a school administrator, may be important in improving administrator-teacher ties. Gittel (2001) found that a narrower span of control for supervisors of flight departure crews resulted in more frequent and intensive exchange. Further research can help establish whether the same holds true in public schools.

Finally, the education and policy literature frequently describes the difficulties teachers and schools face in overcoming the impact of poverty on student academic achievement. Murnane noted that economically disadvantaged children do poorly in school because they "often come to school hungry and in poor health, . . . [and] many of their parents lack the resources and knowledge to reinforce good school-based instruction or to compensate for poor school-based instruction" (2008: 2). The impact of socioeconomic status in our models is quite profound: Student eligibility for free lunch is associated with a 7.6 percent reduction in achievement growth. As previously noted, low-SES students are starting from a lower baseline score, making the reduced rate of growth particularly problematic. Further, the teachers in their classrooms tend to be less experienced and the grade-level teams less educated, further adversely affecting the achievement of the low-SES population of students (see Table 1).

At the same time, teacher human and social capital have significant impacts on student achievement. As indicated earlier, a one standard deviation gain in horizontal tie strength in teacher teams is associated with a 5.7 percent gain in student achievement. And the same gain in vertical tie strength between a teacher and her principal is associated with a 3.7 percent growth in achievement. We find similar results for human capital. These findings suggest that the positive effects of teacher human and social capital on student achievement may go some distance toward offsetting the penalty imposed on students with low socioeconomic status. Indeed, just upgrading the grade-level experience of teachers working in low-SES schools to be comparable to levels found in high-SES schools would help offset the negative effects of low SES. Such findings are particularly important given the minimal impact attained by many reform efforts over the past two decades—particularly in schools with economically disadvantaged students—including numerous curricular "reforms" and a variety of approaches to professional development (for an in-depth critique, see Schneider and Keesler [2007]). Clearly, a fresh, evidence-based approach is needed if the disadvantages that poor students have walking in the schoolhouse door are to be ameliorated by school policy and practice.

Generalizability of Findings

In doing research outside of the for-profit arena, we risk questions about the broader applicability of our findings for management practice. We argue, however, that schools provide a very rich environment for exploring human and social capital. They have historically served as contexts for the development of social capital theory (see Coleman [1988] and the earliest works on social capital, such as Hanifan [1916]). Furthermore, education is an endeavor that requires high levels of human capital to attain high levels of organizational performance. With a relatively homogenous set of organizational activities, limited opportunities for deviation in work organization, and quite consistent organizational structure, schools provide relatively controlled settings in which to explore human and social capital effects. We were thus able to test theory regarding the two forms of capital in a manner consistent with earlier theory development, and in ways that might have been difficult in more heterogeneous contexts.

Second, our measures of teacher human capital are largely context-specific, limiting direct applica-

bility to other settings and occupational groups. Although it is clearly the case that our measure of teaching ability, for example, would not be useful in assessing human capital in nonteaching occupations (or even in teaching other subjects), we offer it not as a general measure of human capital but, rather, as a model for designing measures in future studies that are similarly adapted to their context and thus closer to the outcome of interest. Thus, we believe our *approach* to operationalizing constructs, rather than the measures themselves, is generalizable to other organizations and future research studies.

Finally, as Klein and Kozlowski (2000) noted, it is unusual for individual performance to cumulate to improvements in organizational performance. However, in the context of schools, the key outcome measure from a policy standpoint reflects such a straightforward aggregation; that is, student performance aggregates to school performance, rendering multilevel analyses of our key constructs highly meaningful. It is not surprising that some of the key multilevel statistical tools originated in education (cf. Raudenbush & Bryk, 2002). By undertaking research in contexts such as education, we not only can contribute to significant policy debates, but also can draw on innovative methodological traditions emanating from outside management and develop theoretical insights that are applicable across organizational domains.

Limitations

Although our research contributes to theory and practice, it is not without limitations. One challenge in our research context is that experience and formal education were closely intertwined, since teachers were required to participate in continuing education each year. This is a common problem with education research, and some argue that any positive outcomes attributed to educational attainment may actually be the result of experience (Wayne & Youngs, 2003). Although here we examined contextualized rather than general experience (that is, experience teaching at grade level versus general teaching experience), further research in contexts in which experience is not so closely tied to formal education will help determine the value of mandated continuing education.

Second, we focused our analyses on student achievement—a high-stakes outcome. There are substantive penalties for schools showing low performance under federal law, and various state and local initiatives tie student performance to teacher pay (Rockoff, 2004). However, the very emphasis on student performance itself reflects a particular policy frame. Achievement tests have great appeal to policy makers because they are cheap, they are straightforward to mandate (in contrast, for example, to changing the approach to learning), and they can be publicized (Linn, 2000). However, student performance is an imperfect indicator of desired classroom practice. The American Federation of Teachers, for example, has taken the position that teacher performance assessments should be based on evaluations by other teachers (American Federation of Teachers, 2003). Our measures of human and social capital may predict student achievement on standardized tests, but would the same results be found if the outcome of interest was, for example, pedagogical innovations or peer reviews of teaching practice? To the extent these capture more diverse, and less scriptable, dimensions of teacher performance, it would be useful to explore whether the relationships uncovered in this study would hold.

Finally, we have focused our discussion on teacher-level factors that enhance student performance. However, as our analyses have shown, the bulk of the variance in student performance growth rests at the student level. For example, student absenteeism and SES, which are control variables in our analyses, are important drivers of student achievement, and though politically complex, policy changes directed toward these may have a far greater impact on student outcomes.

Conclusions

Our results offer important insights for theory and practice. They advance theory by unpacking the multilevel and reciprocal relationships and coevolution of human and social capital (Nahapiet & Ghoshal, 1998; Zuckerman, 1988). We show that both human and social capital have important individual- and group-level effects on individual performance. Our results further highlight the importance of considering the cross-level interactions between team social capital and individual human capital. With regard to social capital, by simultaneously examining vertical and horizontal ties, we obtained results having implications for understanding peer networks as well as leader-member relations. We also show the importance of context in conceptualizing and assessing human capital effects on performance. Cumulatively, these results highlight the complexity of the phenomena in organizations and point to a need for their more expansive treatment in future theory and research.

Our findings also have a good deal to say about public policy and practice in schools. Concern about the quality of public education in the United States is long-standing. Our results here suggest

that deficiencies in teacher ability may be one reason for low student performance. Such deficiencies, however, cannot be corrected simply by requiring higher levels of education or advanced degrees. Instead, they will require context-specific approaches to remediation that are focused on actual practice. Our results highlight the benefit of fostering dense ties among teachers as an approach to helping teachers of lower ability. Equally important, our results provide direction for realizing greater benefits from teachers whose abilities are strong. For the more-able teachers, strong ties with peers are a key to unlocking these enhanced benefits both for themselves and for their less-able peers. Thus, effective policy in public education will entail making investments in not just the general human capital of teachers, but also in what we label "capital in context"—which includes a task-specific approach to teacher development, as well as substantially higher investments in fostering social capital in schools.

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