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ARTICLES

The Collective Mediation of a High-Stakes Accountability Program: Communities and Networks of Practice

Paul Cobb and Kay McClain
Vanderbilt University

This article describes an analytic approach for situating teachers' instructional practices within the institutional settings of the schools and school districts in which they work. The approach treats instructional leadership and teaching as distributed activities and involves first delineating the communities of practice within a school or district whose enterprises are concerned with teaching and learning and then analyzing three types of interconnections between them: boundary encounters, brokers, and boundary objects. We illustrate the analytic approach by focusing on one urban school district in which we have conducted an ongoing collaboration with a group of middle school teachers. In doing so, we clarify the critical role that school and district-level leaders can play in mediating state and federal high-stakes accountability policies. We conclude by discussing the implications of the analysis for the process of upscaling and the diffusion of instructional innovations.

Our purpose in this article is twofold.[1] The first is to describe an analytic approach for situating teachers' instructional practices in the institutional settings of the schools and districts within which they work. The approach treats instructional leadership and teaching as distributed activities and involves delineating the communities of practice within a school or district whose enterprises are concerned with teaching and learning. Our second purpose is more pragmatic and involves demonstrating the critical role that school and district-level leaders can play in mediating state and federal high-stakes accountability policies. To address these two purposes, we illustrate the analytic approach by focusing on one urban school district in which we have collaborated with a group of middle school mathematics teachers for the past 4 years. The district is of interest because school and district leaders have responded to a state-mandated accountability program not by attempting to regulate teachers' instructional practices but by giving teachers access to material resources (e.g., instructional materials, joint planning time, release time, outside consultants) and by supporting their development of social and personal resources. These social resources encompass collabo-

Correspondence concerning this article should be sent to Paul Cobb or Kay McClain, Vanderbilt University, Peabody College Box 330, Nashville, TN 37203. E-mail: paul.cobb@vanderbilt.edu or kay.mcclain@vanderbilt.edu

[1]The authors made equal contributions to this article and are listed alphabetically.

rative relationships in which teachers jointly address issues that emerge from their instructional practices. The concomitant personal resources include the teachers' conceptualizations of particular content domains, their understanding of the development of students' reasoning in these domains, and the possibilities they see in their students' solutions and explanations. This case is significant because it is sometimes assumed that high-stakes accountability policies necessarily delimit opportunities for teachers to develop instructional practices that focus on supporting the development of conceptual understandings of significant ideas.

In illustrating the analytic approach, we focus both on the leadership practices of school and district leaders and on teachers' instructional practices. As will become apparent when we document the interconnections between the various communities of practice to which they belong, teachers and leaders constitute significant aspects of the environment for each other (see McDermott, 1976). The members of each community therefore afford and constrain the practices developed by members of other communities. It is in this sense that we speak of the practices of each community being partially constituted by the institutional setting in which its members act and interact. In focusing on the communities of practice in which the functions of teaching and instructional leadership are actually accomplished, we are primarily concerned with what Engeström (1998) described as a middle level between the formal structures of schools on the one hand and the content and methods of instruction on the other.

> The middle level consists of relatively inconspicuous, recurrent, and taken-for-granted aspects of school life. These include grading and testing practices, patterning and punctuation of time, uses (not contents) of textbooks, bounding and uses of the physical space, grouping of students, patterns of discipline and control, connections to the world outside the school, and interactions among teachers as well as between teachers and parents [and administrators]. (p. 76)

Engeström characterized these middle-level features as sense- and identity-building processes and argued that they largely determine the sense of schoolwork and thus the experience of what it means to be an instructional leader, teacher, or student within the institutional setting of a particular school and district. This orientation steers us away from a structural perspective on the school as an institution and toward a focus on leaders' and teachers' activities as they participate in what he terms the taken-for-granted aspects of school life. In adopting this latter orientation, our focus is on schools and school districts viewed as lived organizations rather than as formal structural systems that have been abstracted from the activities of the persons who constitute them.

In the first part of the article, we provide an overview of the district and our collaboration with the middle school mathematics teachers. We then discuss the methodology that we used for analyzing a school or district as a configuration of communities of practice. Against this background, we present the results of an analysis of both the relevant communities of practice in the collaborating district and the interconnections between them. In describing the critical role of school and district leaders in mediating a state-mandated accountability program, we document in some detail that their leadership practices were not solo accomplishments but were instead partially constituted by the institutional setting in which leaders developed and refined such practices. In the final section of the article, we broaden our purview beyond the district by considering the prospects for diffusing and upscaling the innovative leadership and instructional practices that we document. In doing so, we introduce the notion of networks of practice that have considerable spatial reach and that link groups of teachers and leaders in numerous schools and districts whose enter-

prises and practices are broadly compatible. A defining feature of such a network is that innovations developed in one community of practice can diffuse rapidly and be assimilated readily by members of other communities within a network. As we clarify, analyses of the topology of networks and communities of practice can provide guidance for efforts at improvement that aim to transform rather than merely augment currently institutionalized instructional and leadership practices.

BACKGROUND TO THE DISTRICT AND TO OUR COLLABORATION

The district in question, which we call Washington Park, is located in a large city in the southwest United States and serves a 42% minority student population with 46% of the students on free or reduced-cost lunches and 36% of the students receiving special services. The district's seven schools serve Grades K–8. Students in Grades 6–8 attend three of these schools. Two of the schools span Grades 5–8, and the third spans Grades 3–8.[2] The remaining four schools each serve a configuration of Grades K–4. There is considerable variation in the composition of the student population across the three middle schools. In addition, there is high turnover in the student enrollment, even within an academic year. As an example, the student turnover rate at one of the middle schools was 29% during the 2002–2003 academic year, and the English-language learner population doubled during a 2-week period.

A state-mandated testing program was in place when we began our collaborations. In this program, students are tested in mathematics, reading, and language arts at each grade level on a nationally norm-referenced test. The results of these annual assessments are disseminated widely in the local media, and school and district leaders are held accountable for student performance. An effort to improve mathematics and language arts instruction was underway before our collaboration. With respect to mathematics, the district had, for example, adopted a National Science Foundation (NSF) funded middle school curriculum compatible with current reform recommendations—for example, the National Council of Teachers of Mathematics (1999) document *Professional Standards for Teaching Mathematics*—and had received an NSF implementation grant. In addition, the district routinely hired university mathematics educators, many with national reputations, as consultants to conduct professional development sessions with teachers. Similar efforts had been conducted in language arts.

Scores on the norm-referenced state-mandated test have remained consistently high because the district has undertaken these efforts to reform mathematics and language arts instruction. Further, there has been improvement in students' mathematics scores in Grades 6, 7, and 8 over the 4 years of our collaboration with teachers in the district, even in the context of high student turnover and rapidly changing demographics. Teachers and administrators in the district almost uniformly attributed their success in mathematics as assessed by the norm-referenced state-mandated test to the implementation of the NSF curriculum. Comments such as "If we just teach the curriculum, the test will take care of itself" reflect teachers' and administrators' confidence in these instructional materials. However, teachers and administrators also acknowledged that it is "difficult for teachers to really do [the curriculum] well." One teacher described the process of learning to use the materials effectively as follows:

[2]Although the term *middle school* is not entirely accurate in all three settings, we use it nonetheless in the remainder of the article to designate the three schools that housed Grades 6–8.

> It is not like computation, you know, you have the formulas and computation here and go. And so this takes a lot of work and a lot of thinking… . And so, it's an extremely difficult program to teach. So for me, the first two years were literally just keep your head above water and learn something about it. Make sure you got through day by day. Then at the third year I felt I started feeling a little more comfortable knowing what is coming, what were some problems the kids ran into, and that I could fill in a little bit better so that they didn't have those problems.

Because of the perceived challenges of implementation, school and district leaders invested considerable material resources (e.g., both time and money) in professional development activities so that teachers might learn to use the instructional materials as the developers intended.

Our initial classroom observations revealed that most of the collaborating mathematics teachers' instructional practices exhibited fidelity to the materials when we began working with them. In particular, their instruction was guided by the investigations around which the curricular materials are organized, and their sequencing of activities mirrored that advocated by the developers. As an example, the text resources typically engage students in an exploratory activity that is intended to provide them with an opportunity to generalize a process or strategy, such as finding a missing quantity through the use of proportions. In these instances, the teachers carefully guided the students' explorations and then worked to support the emergence of the mathematical generalization in a subsequent discussion. The regularities that we identified in the teachers' instructional practices therefore centered on the manner in which they guided the students through the investigations and activities. Variations in their instructional practices became apparent when we analyzed the ensuing whole-class discussions.

The purpose of whole-class discussions for some teachers was to teach a particular solution method, whereas, for others, the intent was to enable their students to share what they had learned during the investigation. In the first of these two approaches, the teachers seemed to view the prior investigation as a pretext for their introduction of a predetermined solution method, and, as a consequence, whole-class discussions were somewhat disconnected from the prior investigations. In the second approach, the teachers expected that their students would develop relevant mathematical understandings as they engaged in the investigation and, as a consequence, did not intervene to support their learning during whole-class discussions. As an example, in one instance students analyzed graphs to investigate rate of change in a graph as a precursor to understanding slope. Teachers who focused on a predetermined solution method introduced the formula for slope without attempting to relate it to students' activity during the prior investigation. Teachers who focused on students' discoveries assumed that their students had deepened their understanding of slope as they engaged in the prior investigation.

It was apparent from our initial observations that most of the teachers assessed their students' reasoning in terms of their completion of instructional activities and their contributions to whole-class discussions. However, the adjustments that they made when they judged that a significant proportion of their students did not understand typically involved either explaining the process for a second time or asking their students to engage in a second, similar investigation. In doing so, most of the teachers did not seem to view their students' interpretations and solutions as resources on which they could build. Instead, they took an implicit deficit view of their students by using the instructional goal of an investigation or activity as a norm against which to assess their performance. One teacher's explanation of her approach of repeating an instructional activity when she judged that students did not understand as she had hoped is representative in this regard:

> And see, that's kind of like this program is because I do what [the developers] call a launch, like an introduction, and then the kids start working. So I kind of like clue them in on what's coming, this is what you're going to learn, this is what I hope you figure out. I just kind of give them, I know they don't completely understand, so then when they start working with it, then as I walk around, if I notice that there's too many people, sometimes I regroup, and I kind of, teach the whole class again, and go, everybody's asking me how to do number two, so everybody stop, if you understand number two, you can keep working quietly, but everybody else is, and do that a lot, and then, if I notice that nobody's got it, I'll do it again the next day.

At the time that we began working with them, the teachers' efforts to use the curriculum materials as intended were supported by a variety of informal professional networks both within and across schools. Participation in these networks involved conversations that focused on instructional issues and frequent visits to each other's classrooms. At the beginning of our collaboration with them, the teachers all indicated that they viewed their colleagues as resources on whom they could draw when questions or issues arose in the course of their instruction. Mary Jean's response to the question of how she resolved problems that arose in her classroom is typical in this respect:

> Mary Jean: …that is something that I've never been afraid to say, wait a minute, something is rotten here, I'm not understanding it. I'll find about it, and then I would ask… . and that's when I go hunt Pamela down real quick, and find another example, another idea.

Comments by Joan, Beth, and Julian indicate a similar reliance on colleagues.

> Joan: I think I'll probably always go to [Pamela] because I know she's taught the program, she's the more experienced person. So at the beginning of the year, I was asking her about everything, about assemblies, how do I get the kids to lunch, so she was there for that. Now I just go to her for the math stuff… . The questions the kids ask me, then I'm out of time, I'm going, you guys I really don't know, I'll get back to you tomorrow, then I find Pamela, go find Pamela.

> Beth: No, I'll go talk, usually, I will go to [another teacher] first cause she has been here long as I have. We've taught in the program the same amount of years. I'll go and say, you know, how did it go with you, what's going on. And usually her and I will figure something out, and if it's still a big issue, then we bring it to the math meetings that we have once a month.

> Julian: I talk to other sixth-grade math teachers. Other fifth-grade math teachers. I talk to Joseph about it. He's a wealth of information. I go to him. Mari is over at [another school] and I know Mari so I go to Mari. You know, how did you do it? Does this sound appropriate?

It is apparent from these and other teachers' comments that they drew on an array of social resources as a routine part of their practice. Our intent in collaborating with a group of teachers in the district has been to initiate and support the development of a professional teaching community by capitalizing on these resources. To this end, during each of the 4 years of the collaboration, we have conducted a summer work session and half-day work sessions each month during the school year. At the outset, we worked with 14 mathematics teachers representing all three middle schools, and 15 teachers are currently involved in the collaboration. Our pragmatic goal in working with the teachers has been to support their eventual development of instructional practices in which they place students' reasoning at the center of their instructional decision making. In the en-

visioned forms of instructional practice to which the collaboration aims, students' interpretations and solutions are viewed as resources on which the teachers can capitalize to achieve their instructional agenda. Instructional materials would then serve not as blueprints for instruction but as resources that teachers adapt to the context of their classroom as informed by conjectures about both students' reasoning and the means of supporting its development.[3] Furthermore, implementation would become a process of conjecture-driven adaptation rather than one of fidelity of reproduction. However, the complex and demanding nature of instructional practices of this type indicate the importance of social resources, such as those on which we planned to build when supporting the development of a professional teaching community (Gamoran et al., 2003). When situated within such a community, the process of instructional improvement then becomes a collaborative problem-solving activity in which teachers generate knowledge about students' mathematical reasoning and the process of supporting its development (Franke, Carpenter, Levi, & Fennema, 2001).

This overview of the district, the teachers' initial instructional practices, and our proposed collaboration with them serves to describe the setting in which we pursued our primary research goal of investigating conjectures about the means of supporting and sustaining the development of professional teaching communities.[4] To achieve this goal, we conducted a design experiment (cf. Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) in which we tested and revised conjectures about both a learning trajectory for a professional teaching community and the specific means that might be used to support that learning. A detailed discussion of the conjectures that informed our initial plans for working with the collaborating teachers can be found in Cobb and McClain (2001). The analyses that we conducted to inform the ongoing revision of these initial conjectures track the evolution of the activities of the professional teaching community and changes in the participating teachers' instructional practices.

The data we generated to document the learning of the professional teaching community throughout our collaboration with the teachers include semistructured interviews conducted with the teachers each year, video recordings of all work sessions, and copies of all material artifacts produced by the teachers.[5] To document the teachers' instructional practices, we generated modified teaching sets (Simon & Tzur, 1999) each year for each teacher. A modified teaching set consists of classroom observations followed by an audio-recorded semistructured interview with the teacher that focused on instructional planning and on reflections of lessons. Analyses of these data indicate that we had some success in supporting the learning of the professional teaching community and the participating teachers. Within the professional teaching community, we were able to document growth not only in the teachers' mathematical understandings (McClain, 2003) but also in their understanding of students' reasoning as a resource on which they could capitalize to achieve their instructional agendas. In particular, in the course of discussions within the professional teaching

[3]We construe these means of support broadly so that they include the nature of classroom discourse and the classroom activity structure as well as instructional materials and associated tools.

[4]We are in fact investigating these conjectures by collaborating with groups of teachers in two contrasting urban districts. A description of the second district can be found in Cobb, McClain, Lamberg, and Dean (2003).

[5]The process of documenting the learning of a professional teaching community involved identifying the successive norms that became established for general participation, mathematical reasoning, pedagogical reasoning, and strategic norms (i.e., the ways of understanding the institutional setting for mathematics teaching that have become normative within the professional teaching community). A discussion of the criteria that need to be satisfied when identifying communal norms can be found in Cobb, Stephan, McClain, and Gravemeijer (2001).

community, the teachers analyzed student work samples to delineate distinct types of mathematical reasoning and focused on how they can build on their students' mathematical thinking during whole-class discussions. Thus, rather than introduce a predetermined method or expect students to develop relatively sophisticated mathematical understandings without support, some of the teachers assumed a proactive role in which they use their students' reasoning as a resource.

THE INSTITUTIONAL SETTING IN WHICH THE TEACHERS REVISED THEIR INSTRUCTIONAL PRACTICES

The analyses that we have described to this point are internal to the professional teaching community. However, a number of investigations have documented that teachers' instructional practices are profoundly influenced by the institutional constraints that they attempt to satisfy, the formal and informal sources of assistance on which they draw, and the materials and resources that they use in their classroom practice (Ball, 1996; Brown, Stein, & Forman, 1996; Feiman-Nemser & Remillard, 1996; Nelson, 1999; Senger, 1999; Stein & Brown, 1997). The findings of these studies indicate the need to take account of the institutional setting in which the collaborating teachers developed and refined their instructional practices. It is only when we do so that we can adequately explain both our success in supporting the teachers' development of increasingly sophisticated instructional practices and the district's success as assessed by student performance on state-mandated achievement tests. We have therefore complemented our focus on the activities of the professional teaching community and the teachers' instructional practices with analyses of the institutional setting in which the collaborating teachers work.

The approach that we have taken when conducting these analyses involves identifying the communities of practice within a school or district whose missions or enterprises are concerned with the teaching and learning of mathematics. We build from Wenger (1998) by using his three interrelated dimensions that serve to characterize a community of practice: a joint enterprise, mutual relationships, and a well-honed repertoire of ways of reasoning with tools and artifacts. In the following, we clarify each dimension of the professional teaching community in Washington Park by example.

A Joint Enterprise

In the case of the professional teaching community, the joint enterprise was to ensure that students come to understand central mathematical ideas while performing more than adequately on high-stakes assessments of mathematics achievement. This entailed the teachers' developing a relatively deep understanding of the mathematical intent of instructional activities so that they could achieve their instructional agendas by capitalizing on students' reasoning.

Mutual Relationships

In the case of the professional teaching community, these relationships encompass general norms of participation as well as norms that are specific to mathematics teaching, such as norms of mathematical reasoning and the standards to which the members of the community hold each other accountable when they justify pedagogical decisions and judgments. As an illustration, when sharing the results of instructional activities, the teachers routinely challenged arguments that take the goal

of instruction as a normative point of reference and characterized students' reasoning in terms of deficits. In doing so, the teachers held each other accountable to the norm of attempting to tease out differences in students' current capabilities.

A Well-Honed Repertoire of Ways of Reasoning With Tools and Artifacts

In the case of a professional teaching community, this repertoire includes (a) normative ways of reasoning with instructional materials and other resources when planning and organizing for mathematics instruction and (b) normative ways of using instructional activities and other resources to make students' mathematical reasoning visible. The normative ways of reasoning with instructional materials that have emerged within the professional teaching community encompass both the mathematical domain that is the focus of instruction and the diverse ways that students might approach and solve instructional activities. These norms became apparent in discussions as the teachers worked together to plan instructional activities that they would use in their classrooms. In these conversations, the teachers who characterized instructional goals solely in terms of processes that students were to learn for producing answers were typically challenged for failing to explicate the underlying mathematical ideas. Furthermore, in the course of these conversations, the teachers typically envisioned the nonstandard approaches that students might take.

Methodologically, we used what Spillane (2000) referred to as a *snowballing strategy* and Talbert and McLaughlin (1999) termed a *bottom-up strategy* to delineate the communities of practice within the Washington Park district whose missions or enterprises were concerned with the teaching and learning of mathematics. The first step in this process involved conducting audio-recorded semistructured interviews with the collaborating teachers to identify people within the district who influenced their classroom instructional practices in some significant way. The issues addressed in these interviews included the professional development activities in which the teachers have participated, their understanding of the district's policies for mathematics instruction, the people to whom they are accountable, their informal professional networks, and the official sources of assistance on which they can draw. To corroborate these interview data, we also administered a survey that addressed these same issues to all the mathematics teachers in the Washington Park district who taught Grades 6–8. The second step in this bottom-up, or snowballing, process involved interviewing the people identified in the teacher interviews and surveys to understand their agendas as they related to mathematics instruction and the means by which they attempted to achieve those agendas. We then continued this process as we identified additional people in this second round of interviews who actively attempted to influence how mathematics is taught in the district.

The communities of practice that we identified in addition to the professional teaching community as we analyzed these data were the districtwide mathematics leadership community and the school leadership communities in the three schools in which the teachers work.

THE MATHEMATICS LEADERSHIP COMMUNITY

The core members of the mathematics leadership community were the mathematics teacher leaders in each of the three middle schools who received 50% release time from teaching to lead the district's instructional improvement effort in mathematics. A number of teachers were also members

of this community but had peripheral roles. The mathematics teacher leaders were, for their part, full members of the professional teaching community and participated in all sessions.

In addition to the semistructured interviews conducted with the core members, the data generated to document the activities of the mathematics leadership community include a series of follow-up interviews, scheduled monthly meetings, frequent informal discussions, and an ongoing e-mail exchange as well as observations of professional development sessions that the mathematics teacher leaders conducted in the district. These data consistently indicate that the mathematics teacher leaders viewed themselves as members of a broader community of mathematics education reformers and had a relatively deep understanding of and a commitment to the general intent of proposals for mathematics teaching and learning. For example, they attempted to organize mathematics instruction around central mathematical ideas and viewed mathematical communication not merely as a possible instructional strategy but as an important instructional goal in its own right.

The analysis of the data that we generated consistently indicates that the joint enterprise of this community was to improve the mathematics understanding of all students by assisting teachers in developing a relatively deep understanding of both the mathematical ideas addressed in the NSF textbook series and the ways in which students' reasoning might evolve as they complete instructional activities. As part of the process of supporting teachers' learning, the mathematics leaders had developed a district curriculum guide that correlated the NSF text resources with the state standards and provided a pacing guide to ensure coverage of the text resources. The tools with which the members of the mathematics leadership community reasoned as they organized for mathematics teaching and learning therefore included the state standards, the district curriculum guide, the NSF instructional materials, the pacing guide, and samples of students' work that served to document their mathematical reasoning. In contrast to this array of tools, the mathematics teacher leaders all indicated that they made students' learning visible by relying almost exclusively on scores on the state-mandated test.

As part of the process of organizing for mathematics instruction, the mathematics teacher leaders conducted biweekly meetings with the teachers at a particular grade level in each school. Although the mathematics teacher leaders gave priority to the implementation of the curriculum and adherence to the state standards in these grade-level meetings, their larger goal was to support the teachers' development of instructional practices that would support students' development of mathematical understanding as reflected on state test scores. To achieve this goal, the mathematics teacher leaders focused on the teachers' understanding of the mathematical intent of instructional activities when they addressed implementation issues. To this end, they and the teachers worked together to complete instructional activities and examined student work on these and similar activities.

One classroom teacher described this emphasis in the grade-level meetings as follows:

> I would call it a grade-level learning group. It's a grade level math meeting where you go in and you usually pick the topic at the prior meeting [based] on where you'll be. That's where you go in and really look at what are you studying, how close your students are getting. We take a bit of time doing that, then we may tear apart the [mathematics] book. We may sit and look at a fraction book, we have two fraction books. We may say, this is really redundant, these are the same lessons, let's do one and take the other out for expediency's sake. Or we may say, you know, this is really crucial so we need more lessons. I know people are reading this and that, but look at this lesson over here and how relates to it. And this

> one and this one, and this one. We may bring in articles that we found were valuable. Or we may say, you know what, I have no idea what the point is, I have no idea what the form or the function is. We can sit and discuss how important that is, and how it works.

To make mathematics learning visible, the mathematics teacher leaders (MTLs) spent time analyzing standardized test scores, typically in collaboration with the leadership community in each school. Their primary purposes in doing so were to monitor achievement levels in each school at each grade and to identify potential weaknesses in the curriculum strands both within and across grades. The MTLs then typically analyzed the fit between potential areas of weakness and the curriculum to investigate whether there had been "adequate coverage" during the year. It was apparent from these analyses that the MTLs viewed the state test scores as an assessment of not only the students but also the curriculum and the teachers' ability to implement it effectively. For this reason, their first step when investigating a drop in scores was to determine which parts of the curriculum had been implemented the previous year. In conducting these analyses, the MTLs assumed that fidelity to the curriculum correlated strongly with high test scores.

SCHOOL LEADERSHIP COMMUNITIES

The school leadership communities in each of the three schools in which the collaborating teachers work consist of the principal and the assistant principal. In addition, the mathematics teacher leader and one or more teachers in each school were peripheral members. We relied on semistructured interviews conducted with the school leaders to document the activities of these communities, and we triangulated these interviews with the collaborating teachers' descriptions of the settings of their work. These data document that the joint enterprise of each of the school leadership communities is to support mathematics teachers' efforts to improve the quality of mathematics teaching and learning in the district while remaining vigilant about student test scores on state-mandated tests. The interviews indicate that the school leaders, like the mathematics teacher leaders, viewed fidelity to the curriculum as evidence of effective instructional practice. The school leaders at each school characterized an effective classroom as one in which

- There is more than one way to solve a problem.
- There are ample opportunities for students to explain their thinking.
- There is enthusiastic interaction among the students around mathematical ideas.
- Teachers are using formative assessment to plan instruction.

They pursued their agenda for mathematics teaching and learning by providing resources (e.g., texts, materials, release time, attendance at professional meetings), arranging schedules to facilitate collaboration, and modifying observation forms so that they supported reflection rather than assessment.

The primary tools that members of the school leadership communities used as they organized for mathematics teaching and learning were the state standards and the NSF curriculum. These tools were frequently the focus of discussion in regularly scheduled meetings between the leaders in each school and the mathematics teacher leaders and during the classroom observations that the school leaders conducted. The focus in these settings was on fidelity to the curriculum, on the as-

sumption that this entailed alignment with state standards. One principal confirmed this sentiment when he described his job by noting, "If you teach the curriculum, then the test scores will go up. My job is to make sure they teach the curriculum."

It is important to note that the school leaders had a relatively deep understanding of the general intent of current reform proposals in mathematics education. This reflected their engagement in activities conducted as part of an implementation grant funded by the NSF. Their participation included numerous professional development seminars as well as 120 contact hours of mathematics content courses during the past 4 years. In this process, the school leaders had experienced instruction consistent with the vision articulated in National Council of Teachers of Mathematics reform documents. Furthermore, they had come to see these competencies as being crucial to their role as instructional leaders in their schools. For example, the school leaders devoted a portion of their districtwide biweekly meetings to mathematics. In these settings, they completed an instructional activity from the NSF curriculum to develop their own mathematical reasoning and to appreciate the mathematical intent of the curriculum. These experiences supported their belief that fidelity to the curriculum was the primary means of improving student learning as indicated by test scores.

To make mathematics teaching and learning visible, the members of the school leadership communities analyzed state test scores in the context of districtwide administrative meetings and at the school level with members of the mathematics leadership community. As they sought explanations for the scores, the school leaders acknowledged and relied on the expertise of the MTLs. As an example, school leaders typically brought drops in test scores to the attention of the MTLs but left the analysis of possible causes to them. The development of plans to address these deficiencies was also the purview of the MTL. The school leaders, for their part, made resources available to the MTLs so that they could pursue courses of action with respect to the scores.

It is apparent from these descriptions of the mathematics leadership and school leadership communities that the visions they attempted to realize for mathematics teaching and learning were broadly compatible. For the mathematics teacher leaders and the school leaders, mathematics teaching is a complex and demanding activity that requires a deep understanding of students' mathematical reasoning and the mathematical ideas that are the focus of instruction. Furthermore, the mathematics teacher leaders and the school leaders conceptualized instructional goals in terms of mathematical ideas and pursued agendas that were not limited to instructional methods or strategies but also encompassed the nature of students' engagement in classroom activities and the forms of mathematical reasoning that they were developing. Although the school leaders in particular were attentive to student scores on state-mandated tests, it is significant that they and the mathematics teacher leaders participated primarily in the discourse of reform in mathematics education rather than the discourse of high-stakes testing and accountability (see Confrey, Bell, & Carrejo, 2001).

It should also be apparent from the account that we have given of the various communities in the Washington Park district that teachers developed and refined their instructional practices in an institutional setting in which they were consistently supported to implement the NSF curriculum with fidelity. We saw, for example, that teachers' participation in grade-level meetings conducted by mathematics teacher leaders supported their development of relatively deep understandings of central mathematical ideas. The consistently supportive nature of the institutional setting was particularly evident when aspects of a teacher's instructional practice were perceived to be problematic. In such cases, the teacher and a school leader (e.g., the assistant principal or the principal) jointly constructed an improvement plan. The teachers often talked openly about these plans in the

professional teaching community and solicited advice about how they might best approach the identified problems they were experiencing in their classrooms. This deprivatization of instructional practices was made possible by and contributed to an institutional setting in which teachers viewed the mathematics teacher leaders, school leaders, and each other as resources for their learning.

INTERCONNECTIONS BETWEEN COMMUNITIES OF PRACTICE

To this point, we have documented that the practices of the professional teaching community, mathematics leadership community, and school leadership communities were in broad alignment. However, we have not explained how this alignment was sustained or how the practices of the mathematics and school leaders related to and influenced teachers' instructional practices. To address these issues, we have to take the analysis one step further by delineating the interconnections between the various communities that we have identified. In doing so, we distinguish between three types of interconnections: boundary encounters, brokers, and boundary objects.

Boundary Encounters

The first type of interconnection arises when teachers' or leaders' routine participation in the practices of their community involves boundary encounters in which they engage in activities with members of another community. As an illustration, boundary encounters occurred in the Washington Park district when mathematics leaders and school leaders conducted classroom observations. Additional boundary encounters included the grade-level meetings that the mathematics teacher leaders conducted with teachers and the regularly scheduled meetings between the school leaders and the mathematics teacher leader in each school. The mathematics teacher leaders' institutionalized role as authorities with expertise in the teaching and learning of mathematics was readily apparent in these two series of meetings.

Brokers

The second type of interconnection that we documented when analyzing the institutional settings in which the collaborating teachers developed and revised their instructional practices concerns the activities of brokers who were at least peripheral members of two or more communities of practice. Brokers can bridge between the activities of different communities by facilitating the translation, coordination, and alignment of perspectives and meanings (Wenger, 1998). Their role can therefore be important in developing alignment between the enterprises of different communities of practice. In the Washington Park district, the mathematics teacher leaders were the most visible brokers. As we have noted, they were not only members of the mathematics leadership community but were also core members of the professional teaching community and peripheral members of the school leadership community. In this pivotal role as brokers between their own and the other communities, the mathematics teacher leaders had at least partial access to the practices of the professional teaching community and the school leadership community. This in turn enabled them to

provide the school leaders and teachers with access to the practices of each other's communities. One important consequence of their activity as brokers was that they could therefore provide teachers with a voice in the school leadership communities.

Boundary Objects

The third type of interconnection between the communities of practice involves the use of a common boundary object by members of two or more communities as a routine part of their activities. In the Washington Park district, boundary objects include the curriculum materials, the state standards, and reports of students' test scores. As Wenger (1998) noted, boundary objects are based on what he termed *reification* rather than participation.[6] Wenger defined reification as "the process of giving form to our experience by producing objects that congeal this experience into 'thingness'" (p. 58). He argued that in creating reifications, "we project our meanings into the world and then we perceive them as existing in the world, as having a reality of their own" (p. 58). However, as he went on to emphasize, reifications cannot capture the richness of lived experience precisely because they are frozen into a concrete form such as a text. As a consequence, although a reifying object is a relatively transparent carrier of meaning for members of the community in which it was created, there is the very real possibility that these objects will be used differently and come to have different meanings when they are incorporated into the practices of other communities. Even when this occurs, common boundary objects that are used differently in different communities can nonetheless enable the members of these communities to coordinate their activities. Consequently, as Star and Griesemer (1989) demonstrated, successful coordination does not require that members of different communities achieve consensus. Boundary objects do not therefore carry meanings across boundaries but instead constitute focal points around which interconnections between communities emerge.

In our experience, the role of boundary objects is typically far less visible to leaders and teachers than are interconnections that involve boundary encounters and brokers. Their inclusion in an analysis of the institutional setting in which a group of teachers have developed their instructional practices is therefore crucial if we are to document the inconspicuous, recurrent, and taken-for-granted aspects of school life. In the case of the Washington Park district, the curriculum materials and the state standards were constituted as boundary objects between all three communities as their members organized for mathematics instruction. However, only reports of students' scores on the state-mandated test were constituted as boundary objects as the members of the various communities made mathematics teaching and learning visible.

Given Star and Griesemer's observation (1989) that boundary objects do not carry meanings across boundaries, the compatibility in the ways that members of the various communities used the state standards, curriculum, and test scores needs to be explained. Two observations are relevant in this regard. First, boundary encounters, particularly those in which the mathematics

[6]Reification as Wenger (1998) defined it should not be confused with Sfard's use (1991, 1994) of this same term. For Sfard, reification is the process by which mathematical objects are constructed from operational mathematical processes. Wenger's use of the term is less technical and refers to the process by which members of a community create objects that, for them, carry particular practice-based meanings. As he made clear, the process of reification complements participation in the sense that mutual engagement typically involves the use of artifacts that are the product of prior reifications.

teacher leaders acted as brokers, constituted contexts in which the members of the different communities could explicitly negotiate how they used the state standards, curriculum materials, and students' test scores. For example, the mathematics teacher leaders had access to the ways in which the school leaders used instructional materials and could give the school leaders access to the ways in which they and the teachers used these materials. As a consequence, differences in uses of this and other boundary objects could become an explicit topic of conversation in the meetings between the school leaders and mathematics teacher leaders. Similar comments apply to the mathematics teacher leaders' participation in the professional teaching community and to grade-level meetings that they conducted with the teachers in each school. In each of these cases, the boundary objects supported brokering and the bridging of perspectives, thereby contributing to the alignment of the enterprises of the various communities. More generally, Wenger (1998) noted that mutual engagement and reification offer two complementary ways of attempting to shape the future and that one is rarely effective without the other.

Our second observation concerns the practices in which the various boundary objects originated within the district. For example, the state standards and the reports of test scores were primarily grounded in the practices of school leaders as they monitored students' performance on the state-mandated test. The constitution of the state standards and test scores as boundary objects enabled teachers and mathematics teacher leaders to contribute to the enterprise of the school leadership communities. In contrast, the adopted curriculum was primarily grounded in the practices of teachers and the mathematics teacher leaders. Its constitution as a boundary object enabled the school leaders to contribute to the enterprises of the mathematics leadership and professional teaching communities. The alignment that we have documented between the practices of the various communities was continually regenerated as the members of particular communities contributed to the enterprises of other communities in this manner.

In concluding this characterization of the Washington Park district, we note that the analysis of interconnections based on boundary objects is pragmatically useful in that it can inform our efforts to support the learning of the professional teaching community. As an illustration, we consider it significant that the only tool for making mathematics teaching and learning visible that was constituted as a boundary object was grounded primarily in the practices of the school leadership community. As we have seen, the negotiation of the ways in which the members of various communities used students' test scores enabled teachers and the mathematics teacher leaders to contribute to the enterprise of the school leaders. In contrast, the samples of students' work that teachers generated to document their mathematical reasoning were a focus of discussion only in grade-level meetings with the teacher leaders. As a consequence, school leaders had few opportunities to negotiate their understandings of students' reasoning with the members of the other communities. This in turn delimited their contributions to the enterprises of the professional teaching and mathematics leadership communities. In our future work in the district, we will therefore endeavor to support the constitution of student work as a boundary object between all three communities.

As this example illustrates, analyses of the institutional setting of teaching that include a focus on interconnections between communities can provide a perspective from which to consider whether collaborations with teachers should entail concerted attempts to bring about changes in the settings in which they have developed their current instructional practices. In addition, analyses of this type can inform the development of testable conjectures about the means of bringing about such changes. The approach that we have illustrated was in fact developed as a general way

of documenting and analyzing the specific institutional settings in which particular groups of teachers work that can feed back to inform efforts to support their learning. The potential value of such an approach is that it can support teacher development efforts by enabling researchers and teacher educators to monitor the institutional settings of the sites in which they are working on an ongoing basis.

DISCUSSION

In stepping back from the Washington Park district, we first foreground key characteristics of the analytical approach and then draw together the central aspects of the sample analysis. We conclude by discussing the implications of the analysis for the process of working in multiple districts and the diffusion of instructional innovations.

It should be clear that in identifying relevant leadership communities, we do not assume that school and district leadership resides exclusively with the individuals who occupy designated leadership positions. Instead, we follow Spillane, Halverson, and Diamond (1999, 2001) by discerning how various leadership functions are actually accomplished with the expectation that we will find that many are in fact distributed across several people who use a range of tools to accomplish those functions. Similarly, the analytic approach that we have illustrated characterizes teaching as a distributed activity. At first glance, this assumption might seem highly questionable for districts where, in contrast to Washington Park, teachers work in relative isolation and have limited opportunities for collaboration with each other. However, this contention becomes plausible when we note that the approach that we have taken focuses not on actions of individual teachers working alone in their classrooms but on the functions of teaching as they are accomplished in schools and school districts. As we have illustrated, these functions are not restricted to interacting with students in the classroom to support their mathematical learning but also include

> *Organizing for mathematics teaching and learning* by, for example, delineating instructional goals and by selecting and adapting instructional activities and other resources.
>
> *Making mathematics learning and teaching visible* by, for example, posing tasks designed to generate a record of students' mathematical reasoning.

When we analyze how these latter two functions are actually accomplished in specific cases, it almost invariably proves to be the case that a number of persons in various designated positions within the school and district are involved in accomplishing them and that they use a variety of tools as they do so. As an illustration, the mathematics teacher leaders used the state standards and the curriculum materials as they organized for mathematics teaching and learning by conducting grade-level meetings and by meeting regularly with the members of the leadership community in each school.

As a point of clarification, we should stress that this distributed perspective on teaching does not imply that people within a school or district necessarily coordinate their activities seamlessly or smoothly. Although this was the case in the Washington Park district, we have reported an analysis of a second district elsewhere (Cobb et al., 2003) in which mathematics teaching was a site of tension and struggle as people within that district pursued conflicting agendas. More generally, the immediate institutional setting within which teachers develop and refine their instructional practices is constituted as members of different communities of practice pursue sometimes-con-

flicting instructional visions and gauge the extent to which their visions have been realized in classrooms.

Consistent with the distributed perspective that we have proposed on mathematics teaching, the analytical approach characterizes individual teachers' instructional practices as situated and as partially constituted by the institutional setting in which they work. For example, the instructional practices of the collaborating teachers were situated in that they involved

- Reasoning with the NSF instructional materials and with work samples that served as records of students' reasoning.
- Having coordinated schedules and joint planning time.
- Having access to computer labs and other physical resources.
- Having access to peers when difficulties arose in their classrooms.
- Drawing on their understanding of their students' mathematical reasoning and the intent of the NSF materials to justify their pedagogical decisions to members of the professional teaching community and the mathematics leadership community.
- Receiving assistance rather than assessment from mathematics teacher leaders and school leaders during classroom observations.

Taken together, these aspects of the institutional setting in which the collaborating teachers developed their instructional practices provided them with access to resources for improving their instructional practices while simultaneously insulating them from high-stakes accountability pressures.

Similarly, the analytical approach also produced situated accounts of the activities of the mathematics teacher leaders and the school leaders. For example, the mathematics teacher leaders' activity was situated in that they

- Were constituted as content experts as they interacted with members of both the professional teaching community and the school leadership communities.
- Reasoned with the NSF instructional materials and state standards when organizing for mathematics teaching and learning.
- Had access to and could influence the practices of school leaders.
- Had the autonomy and material resources to investigate and address perceived problems with test scores.
- Had access to and could influence teachers' instructional practices during classroom visits and grade-level meetings.

The responsibilities of mathematics teacher leaders as they were constituted in the Washington Park district involved supporting teachers to improve their instructional practices while collaborating with school leaders to ensure that test scores continued to be acceptable.

The school leaders' activity was situated in that they

- Were held accountable by district leaders and the community for test scores.
- Reasoned with the NSF instructional materials and state standards when organizing for mathematics teaching and learning and with test scores when making mathematics teaching and learning visible.

- Negotiated their interpretations of the instructional materials and test scores with the mathematics teacher leader in their school.
- Deepened their understanding of the mathematical intent of the NSF instructional materials during biweekly meetings of school leaders in the district.
- Observed teachers' instructional practices during classroom visits and addressed perceived difficulties by formulating an improvement plan in collaboration with the teacher.

The responsibilities of school leaders as they were constituted in the Washington Park district involved collaborating with mathematics teacher leaders in their efforts to improve the quality of mathematics teaching and learning while remaining vigilant about test scores.

In the first part of this article, we note that the Washington Park district is of particular interest because school and district leaders have responded to a state-mandated accountability program not by attempting to regulate teachers' instructional practices but by giving teachers access to material resources and by supporting their development of social and personal resources. The analysis that we present demonstrates that the roles of individual school leaders in mediating the state accountability program were not solo accomplishments but were instead partially constituted by the institutional setting in which they worked. For example, we point to the opportunities for the school leaders to deepen their understanding of the learning and teaching of mathematics through courses that they had been required to take. We also saw that in meeting regularly with the mathematics teacher leader in their school, they had the opportunity to negotiate their interpretations of the NSF instructional materials with a person who was constituted in the district as a content expert. These and other aspects of the institutional setting in which the school leaders worked afforded and constrained their development of leadership practices that involved supporting teachers' learning by giving them access to resources and by engaging in the discourse of educational reform rather than of high-stakes testing when they interacted with them. In a very real sense, what it meant to be a school leader in the Washington Park district was partially constituted by the institutional setting in which the school leaders developed and refined their leadership practices.

The analysis that we present of the Washington Park district substantiates research in the fields of educational policy and educational leadership that has sought to identify characteristics of schools in which innovative instructional practices are likely to be sustained. As Newman and Associates (1996) documented, facets of the organizational capacity for change and improvement of such schools include knowledge and skills, shared visions, collaboration among staff, classroom autonomy, and collective responsibility for students' learning. The analysis of various communities that comprise the Washington Park district and the interconnections between them serve to specify the underlying processes that give rise to these characteristics in this particular case. For example, we illustrate how the institutional niches in which the members of each community developed and refined their practices involved considerable autonomy while simultaneously giving them access to new skills and forms of knowledge. Similarly, we clarify how an alignment between the enterprises and practices of the different communities involved shared visions, collaboration, and collective responsibility for student learning was generated and sustained. More generally, analyses of the type that we have illustrated complement those conducted in the fields of educational policy and educational leadership by documenting the processes by which teachers and leaders in particular schools and districts collectively generate characteristics of schools associated with a high capacity for change and improvement in mathematics teaching and learning.

Given the success of teachers and leaders in the Washington Park district in supporting students' mathematical learning, a question that naturally arises is that of how innovative aspects of their practices might be disseminated to other districts. In addressing this issue, we draw on Brown and Duguid's work (2000) to introduce the notion of a *network of practice*. Brown and Duguid clarified that networks of practice have considerable spatial reach that transcend the constraints of direct interaction. A defining feature of such a network is that innovations developed in one community of practice can diffuse rapidly and be assimilated readily by members of other communities. As an illustration, the mathematics teacher leaders and most members of the professional teaching community in the Washington Park district considered themselves to be members of a nationwide community of mathematics education reformers. This broader community is not a tight-knit community of practice in which people negotiate meanings directly as they interact while engaging in joint activities. Instead, it is a network of practice that links groups of teachers and leaders in numerous schools and districts whose enterprises and practices are broadly compatible.

Brown and Duguid (2000) emphasized that people whose local community of practice is part of such a network are separated from other people whose local communities are oriented by different enterprises and are thus part of different networks in terms of dispositions, attitudes, and knowledgeability. Brown and Duguid also clarified that networks of practice often correspond to occupational groups. In the case of the Washington Park district, for example, the mathematics teacher leaders, school leaders, and teachers differed from each other in terms of their concerns and interests even though the enterprises of their respective communities were aligned.

The relevance of the notion of networks of practice to the issue of upscaling becomes apparent once we note that innovations are not taken up uniformly but instead diffuse according to what Brown and Duguid (2000) referred to as the topology of networks and communities of practice. As they put it, innovations "leak" along networks of practice while sticking between communities of practice in different networks. Brown and Duguid's account of diffusion indicates that it might be possible to disseminate instructional and leadership innovations in the Washington Park district successfully to other districts that already have a high capacity for change and improvement. In contrast, their analysis indicates that these innovations are unlikely to diffuse to school districts with a limited capacity for change even when concerted efforts that involve newsletters, websites, listservs, and so forth are made to support this process. This is particularly the case for other urban districts in high-stakes testing environments where administrators have responded to accountability pressures by attempting to monitor and regulate teachers' instructional practices.

The analysis that we present documents that the Washington Park district differs significantly from most other urban districts in terms of what it means to be a teacher and an instructional leader. The analysis also illustrates that teachers' and leaders' attitudes and dispositions are not solo achievements but are partially constituted by the institutional setting in which they work. Taken together, these observations imply that upscaling an innovation from a high-capacity district such as Washington Park to other urban districts cannot be accomplished merely by attempting to develop more effective ways to reify the innovation. This is the case even if new information technologies are used (Brown & Duguid, 2000). To be successful, the dissemination process would have to involve the restructuring of the target districts as lived organizations such that the communities of practice that constitute them might become part of the same networks of practice as the corresponding communities of the high-capacity district. This required restructuring process is both profound and daunting in that it penetrates the inconspicuous, recurrent, and

taken-for-granted aspects of teaching and leadership. However, in the absence of such a restructuring, it is highly probable that even if objects that reify the innovation are seen as being relevant, they will be used in very different ways and come to have different and quite possibly conflicting meanings when they are incorporated into the practices of communities in the target districts. As the term *travel* is frequently used to describe the process of upscaling, it is worth noting that this metaphor is grounded in cases where innovations "leak" from one community of practice to another within a network of practice. It is only in such instances that reifying objects are perceived to function as relatively transparent carriers of meaning by members of different communities.

The notion of networks of practice goes some way toward explaining the relative ineffectiveness of most large-scale educational reform efforts. It also serves to clarify the daunting challenges involved in upscaling instructional and leadership practices that place students' mathematical reasoning at the center of decision making. The perspective that this construct offers on the process of dissemination is consistent with Rogers's seminal analysis (1995) of the features of an innovation and the mechanisms of communication that influence the success or failure of diffusion. In summarizing Rogers's findings, Zaritsky, Kelly, Flowers, Rogers, and O'Neill (2003) noted that "among the factors relevant to successful innovation is perceived relative advantage: the degree to which an innovation is perceived as better than the idea, product, or technique it hopes to supersede" (p. 33). Zaritsky et al. explained that measures of relative advantage include complexity, or the degree to which the innovation is perceived as being relatively difficult to understand and use, and compatibility, or the extent to which the innovation is perceived as being compatible with existing values and needs. In our terms, *complexity* and *compatibility* are measures of the extent to which the practices of different communities are aligned. It is therefore understandable that, on our reading, the cases of successful innovation that Rogers discussed to illustrate his perspective are cases of "travel" within established networks of practice.

As Zaritsky et al. observed, the application of Rogers's analysis (1995) of diffusion to educational settings would restrict dissemination efforts to innovations that fit with teachers' and administrators' current practices. In contrast, current reform efforts in mathematics education aim to penetrate what Gamoran et al. (2003) termed the *instructional core* of basic suppositions and assumptions about learning, teaching, and mathematics. Gamoran et al.'s observation strongly suggests that Rogers's analysis cannot, by itself, provide adequate guidance for reform efforts that seek to transform rather than merely augment the instructional core by supporting teachers' development of increasingly sophisticated instructional practices. Instead, it will also be important to attend to the local topology of networks and communities of practice. The analysis that we present demonstrates an approach for doing so that is specifically tailored to the needs and interests of researchers and teacher educators. In this regard, the analytic approach can best be viewed as a tool that is designed to support transformative educational change as iterative processes of continual improvement.

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