Architectures for Learning:

A Comparative Analysis of Two Urban School Districts

An Occasional Report

by

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Introduction

Since the 1990s, educational researchers have increasingly come to see the problem of educational reform as one of learning. In particular, scholars point to the ways that new federal, state, and local policies often require implementers to learn new ways of carrying out their work (Cohen & Barnes, 1993). The learning demands on teachers have become especially intense as policy makers have increasingly set their sights on classroom instruction and put forth visions of instruction that depart substantially from many teachers' existing practice (EEPA, 1990; Cohen & Hill, 2001; Spillane, Reiser & Reimer, 2002). Unlike *additive* reforms (e.g., compensatory education for Title I students), today's policies demand *transformation* of the core of teachers' instructional practices—transformations that require considerable effort, time, and support (Thompson & Zeuli, 1999).

This problem of learning has fallen squarely into the laps of district leaders. Once viewed as the main obstacle to reform, districts are now being asked to oversee instructional improvement on a heretofore unprecedented scale (Hightower, Knapp, Marsh, & McLaughlin, 2002). Many have responded by adopting uniform curricula and providing increased levels of professional development. Others have established integrated programs for students and staff guided by common frameworks for curriculum, instruction, assessment and learning climate (Newman, Smith, Allensworth, & Bryk, 2001). All have insisted that staff modify curriculum to align with state standards and assessments.

Despite all of this activity, the question remains: Are teachers actually acquiring the knowledge and skills required for implementing new and better practices? And, if so, what role has the district played in fostering that learning? Research conducted to date provides incomplete answers to these questions. The most well-established body of research on teachers' responses to the introduction of new, ambitious reforms suggests that teachers have a tendency to gravitate toward approaches that are congruent with their prior practices (Spillane 2000), to focus on surface manifestations (such as discrete activities, materials, or classroom organization) rather than deeper pedagogical principles (Spillane, 2000; Spillane & Callahan, 2000; Spillane & Zeuli, 1999; Stein, Grover, & Henningsen, 1996), and to graft new approaches onto existing practices without altering classroom norms or routines (Cuban, 1993). However, most of this research has focused on teachers as individuals, often in isolation from their organizational contexts.

Other research has examined the influence of teachers' collegial and interpersonal relations on reform implementation. These studies have noted that teachers' professional communities are a crucial site for learning (Franke & Kazemi, 2001; Gallucci, 2003; Little, 1982; Little, 2003; McLaughlin & Talbert, 2001; Smylie & Hart; 1999; Stein, Silver, & Smith, 1998; Stein & Brown, 1997) and provide evidence that teachers' organizational context and patterns of interactions shape how they learn (Coburn, 2001; Hill, 2001; McLaughlin & Talbert, 2001; Spillane, 1999). By and large, however, this work has paid scant attention to the processes by which learning occurs in teacher communities and the manner in which those processes are embedded in and influenced by the organizational milieu in which teachers work.

In this paper, we explore the usefulness of a particular theoretical lens—communities of practice theory—for understanding (and ultimately guiding) how districts can create organizational environments that foster the learning of teachers (Lave & Wenger, 1991; Wenger, 1998). Following Wenger (1998), we call such environments "architectures" for learning. By and large, research has been silent on districts' development of such architectures—and teachers' responses to them. With a few noteworthy

exceptions (Cobb, McClain, de Silva Lamberg, & Dean, 2003; Wechsler, 2001), even studies that have utilized a community-of-practice perspective have focused on meaning making *within* school-based, micro communities of teachers and have not addressed how teachers' participation in these micro communities is shaped by district policy makers' initiatives and designs for learning.

This paper builds on our earlier work in which districts were characterized as multiple, overlapping communities of practice (Coburn & Stein, 2006). Most districts, we argued, comprise many distinct communities of practice including, but not limited to, a district leadership community, a school principal community, a community of staff developers or coaches, and a whole host of teaching communities (Cobb et al, 2003; Spillane, 1998; Wechsler, 2001). We argued that educational reform can be viewed as an attempt by members of one community (in this case, district leaders) to influence the practice of other communities (e.g., teachers' micro communities within schools). Because district leaders seldom interact directly with the micro teacher communities they seek to influence, they identify or create "stuff" that embodies their vision (e.g., curricular frameworks, directives, or procedures) and launch them on journeys that cross the boundaries of a variety of communities (i.e., they "travel" from central office to principals to coaches to teachers). In addition, leaders create opportunities for interaction between various communities of practice (e.g., joint workshops for coaches and principals). Because of the many boundary crossings that must be negotiated as people and "stuff" move across these disparate communities, we propose that teacher learning is determined not only by their interactions *within* their local communities—as already noted by the literature on teacher professional community—but also by the *nature of connections* between their local communities and other communities in the district.

The purpose of this paper, then, is to investigate and elaborate the mechanisms by which connections between communities mediate teachers' learning in response to district policy. We do this by probing the nature of connections between the central office communities and local teacher communities in two similar initiatives located in two different urban districts. Although both were focused on the implementation of a new standards-based mathematics program, their methods for "rolling out" their respective initiatives were very different. In particular, the connections that were forged in one district meaningfully linked participants across disparate communities leading to teacher learning that was aligned with reform goals. The connections created in the other district, on the other hand, coordinated actions but did not spur meaningful teacher learning, thereby leading to superficial enactment of reform goals.

Communities of Practice as a Theoretical Lens

In the communities-of-practice perspective, learning is seen as profoundly social. Individuals "learn" as they participate in the practices of communities and construct identities in relation to those communities (Wenger, 1998). The term "community of practice" refers to a group of individuals who, through the pursuit of a joint enterprise, have developed shared practices, historical and social resources, and common perspectives. This view of community privileges the "lived" rather than the "designed" aspects of our world. Rather than assuming that communities reside in formal organizational structures (such as grade levels, subject matter departments, or even entire schools), this conceptualization locates community in any place where individuals opt into relationships with one another characterized by mutual engagement, joint enterprise, and shared repertoire.[1]

Learning *Within* Communities of Practice

Learning within communities of practice is conceptualized as the ways in which communities gradually transform their practices through on-going negotiation of meaning. This negotiation of meaning, according to Wenger (1998), occurs through the dynamic interrelationship of participation and reification. *Participation*, as in common usage, is defined as engaging in (or taking *part* in) some activity or enterprise. Although Wenger defines *reification* more broadly than the dictionary definition, in this paper, we use the term reification to mean a concrete object that embodies a set of ideas or processes. A typical example would be curricula, the tangible pages of which comprise a "record" that can be used to guide or monitor instructional practice. Curricula (reifications) provide a useful counterpoint to teaching practice (participation) because they reify or "hold steady" a set of ideas and processes across time and space.

The meanings embodied in reifications, however, are always partial. Individuals (especially those who come from communities other than the community that created the reification) imbue them with different meanings and various degrees of significance. When a community engages with a reification, it serves as a "point of focus" around which the negotiation of meaning (learning) occurs. In fact, reifications can be viewed as *requiring* participation to make them meaningful in the context of on-going practice. By the same token, participation also requires reification to be meaningful. Otherwise, participation becomes a string of experiences without anchoring or mooring and there is no mechanism by which to uncover and coordinate differences in meaning among members. Thus, it is the *interplay of reification and participation* that creates new possibilities for the negotiation of meaning and new opportunities for communities to adjust their participation, renegotiate their enterprise, and continue to develop their shared repertoire over time.

Learning *Between* Communities of Practice

As noted earlier, the social landscape of a district comprises multiple, overlapping communities of practice. Each has its own shared history of learning, histories that create discontinuities—boundaries—between those who share the history and those sho do not. These boundaries reveal themselves by the learning that is required to cross them. It is difficult for individuals to "pick up" the talk or tasks of

an unfamiliar community because the meanings that are invested in them are rooted in unspoken, tacit understandings that have developed over a long period of co-participation.

In system-wide reform efforts, district leaders are faced with the daunting task of fostering roughly similar forms of learning across hundreds of professionals—professionals who belong to diverse communities of practice. As noted earlier, leaders typically do this by creating reifications that are shared with the diverse communities and by providing opportunities for individuals from different communities to interact with one another. When reifications traverse multiple communities, they are called *boundary objects*. For example, pacing guidelines produced by a district central office and then passed along to staff developers who, in turn, introduce them to teachers would be considered to be a boundary object. Because the guidelines are meant to be used by multiple communities of practices and sit at the nexus of perspectives, they—as do all boundary objects—have the *potential* to coordinate perspectives and spur similar forms of learning across multiple communities.

When a boundary object is introduced into diverse communities, however, the originator (in this case, the district central office) has limited control over how it will be interpreted and used by the various communities. Using a boundary object to orchestrate learning across disparate communities requires processes of *coordination and translation* between and among those communities. Rather than expecting that diverse communities will interpret a boundary object as intended by the central office, leaders must anticipate the need for and design activities that promote the development of synchronized understandings through cross-community meaning making. These activities are best captured with Wenger's concept of "alignment" (Wenger, 1998; p. 178) where the work of alignment is seen as "bridging time and space to form broader enterprises so that participants become connected through the coordination of their energies, actions, and practices" (p. 179). Such connections allow individuals to situate their actions within a shared vision and to feel motivated to engage in action in concert with others to achieve goals larger than those which may be immediately visible within their own communities.

The Work of Alignment

The work of alignment involves boundary spanning between and among multiple communities. In addition to boundary objects, it relies on brokers (individuals who use their memberships in multiple communities to carry practices between them) and boundary practices (regular, on-going forums for mutual engagement for individuals from different communities, the purpose of which is to sustain a connection across boundaries). Just as the possibility of learning *within* communities of practice is created by the interplay of reifications and participation, so, too, the possibility of learning *across* communities of practice is created by the interplay of boundary objects (reifications) and brokers and boundary practices (forms of participation).

Frequently, teacher communities of practice are expected to learn from district reform initiatives in ways that rely heavily on reification—for example, when teachers encounter policy solely in the form of boundary objects such as a new curriculum. Reifications alone, while efficient for reaching large numbers of people, have limited effectiveness in coordinating meanings because there is not enough overlapping experience between the communities that created the reification and the community that encountered it to create a "coordinated, relevant, or generative meaning" (p. 65). In cases of insufficient participation, Wegner predicts/theorizes that teachers' relations to the broader enterprise will be literal

and procedural; coordination centers on compliance rather than participation in meaning. In these cases, the boundary objects can reinforce the very boundaries they are meant to cross. Alignment can also suffer from a disproportionate emphasis on participation. In the absence of shareable artifacts that create fixed points around which to coordinate activities, coordination is difficult to achieve; it becomes "too vague, illusory, or contentious to create alignment." (p. 187).

Alignment is a key ingredient of the large-scale, coordinated forms of learning that are required in successful district-wide initiatives. Without it, the energies and actions of different communities cannot be galvanized into socially organized action toward a common purpose. As noted earlier, new forms of engagement within an individual, micro community of practice will spur learning *within* that particular community, but they will not—on their own—*connect* that learning to the broader enterprise of whole-district reform. It is through consciously designed processes of *alignment* that individuals become invested in tasks that are defined beyond the engagement of their own community. Thus, alignment is—or should be—a central consideration in district leaders' architectures for learning (Wenger, 1998).

The Study

In this paper, we examine the processes of alignment by which connections were formed across multiple communities within two separate districts, both of which were initiating similar reforms at the same point in time. We examine these connections in terms of the interplay between boundary objects and opportunities to participate (brokers and boundary practices), seeking to understand how tradeoffs between them impacted the process of alignment and, ultimately, the opportunities for learning within local, micro communities of practice. We begin by examining the nature of each district's learning architecture, including both their formal designs for teacher learning and the enactments of these designs. Next we examine the "lived" communities of practice that reside closest to the "action" of the classroom (communities comprising teachers, coaches, and/or principals) and describe the ways in which meanings were negotiated within and between these so-called "local, lived" communities. The contrasts between the two districts—both in terms of their designs for learning and the nature of their lived communities—are then used to advance our understanding of the ways in which the interplay of boundary objects and opportunities for cross-community participation comprise an important feature of districts' architectures for learning.

The patterns reported herein are based on data collected as part of a larger study that examined the interactions between district strategy, human and social capital, type of curriculum, classroom instruction, and student learning in two districts (Stein, Coburn, Leana, Pil, and Gill, 2001). The Capital City School District (an urban district in southwestern United States) adopted *Investigations in Data, Number and Space* in the summer of 2003;[2] Region X in the New York City public school system adopted *Everyday Mathematics* at the same point in time. Each district expected *all* elementary schools to use their respective curriculums and all teachers to participate in professional development. Both districts have a history of underachievement in mathematics and serve primarily high-poverty neighborhoods that include large numbers of recent immigrants. The findings described in this paper represent key themes and patterns in a subset of the data drawn from the first two years of each district's reform.

Sampling

The number of communities of practice within each district is extremely large; hence it was not feasible to explore the connections among all of them. For the present paper, we investigate the ways in which school personnel in two elementary schools in each district are connected to their colleagues and other communities in the district. We selected these four schools[3] from our larger pool of eight case study schools in the study. We selected the school in each district that had was nominated as having high capacity teachers and strong social capital and the school in each district that was nominated as having low capacity teachers and low social capital.

Data Sources

Information about the district-designed architectures for learning was based on interview and observational data gathered from several levels within each district. In both districts, the key leader involved in instructional decision making was interviewed—the deputy chancellor in New York City and the superintendent in Capital City,[4] as well as the director of mathematics in both districts. In New York City, we interviewed the district director of mathematics two times during the first two years and her assistant for elementary mathematics once. In Capital City, we interviewed the director of mathematics two times. In NYC, we also interviewed the leader directly charged with overseeing elementary mathematics instruction in the particular region in which we focused our data collection efforts (two times) as well as the regional superintendent of that region (once). Finally, we observed district-led meetings and professional development sessions in both districts (n=14 full days in NYC and n=10 in Capital City). Transcripts of interviews and observation writeups were examined to determine (a) the formally designated roles and structures for supporting mathematics reform; and (b) how those roles and structures actually played out, that is the nature of the interactions that characterized their enactments.

In each school, we conducted 5 interviews and 6 classroom observations per year with each of 6 focal teachers, selected to represent a range of instructional approaches and a range of grade levels (n=24 teachers). We supplemented work with focal teachers with 2 interviews a year with the mathematics coach (n=6 coaches), 2 interviews per year with the school principal (n=4 principals); 1 interview a year with 6 additional teachers in each school (which we call non-focal teachers, n=24 additional teachers); as well as observations of 3-5 occasions in each school where teachers interacted on matters of mathematics instruction (professional development, grade level meetings, coaching sessions, etc.).

Because communities of practice cannot be presumed to exist (they do not necessarily follow formally designated organizational structures or units), we treated the identification of communities of practice as an empirical question. We identified so-called "lived" communities through structured social network interviews with mathematics coaches, principals, focal and non-focal teachers, and selected individuals at the district level. We used questions designed to find out who each person talked with about mathematics instruction, the frequency and content of their interaction, as well as why they talked with some people and not others (see appendix). We then supplemented the interviews by observing occasions where teachers and others interacted, including professional development, teacher meetings, and leadership team meetings. This approach helped us better understand the nature of interaction in teachers' lived communities.

FINDINGS

Both Capital City School District and NYC Region X began with ambitious, district-wide visions for the improvement of mathematics. We begin this section with a review of the systems that district leaders put into place to support teachers and other professionals who were expected to carry out the reforms, followed by findings related to how interactions unfolded within these systems with a special focus on boundary practices and boundary objects. Then we transition to a discussion of how teachers and others interacted in their micro-communities of practice in the four case-study schools.

District Learning Architectures

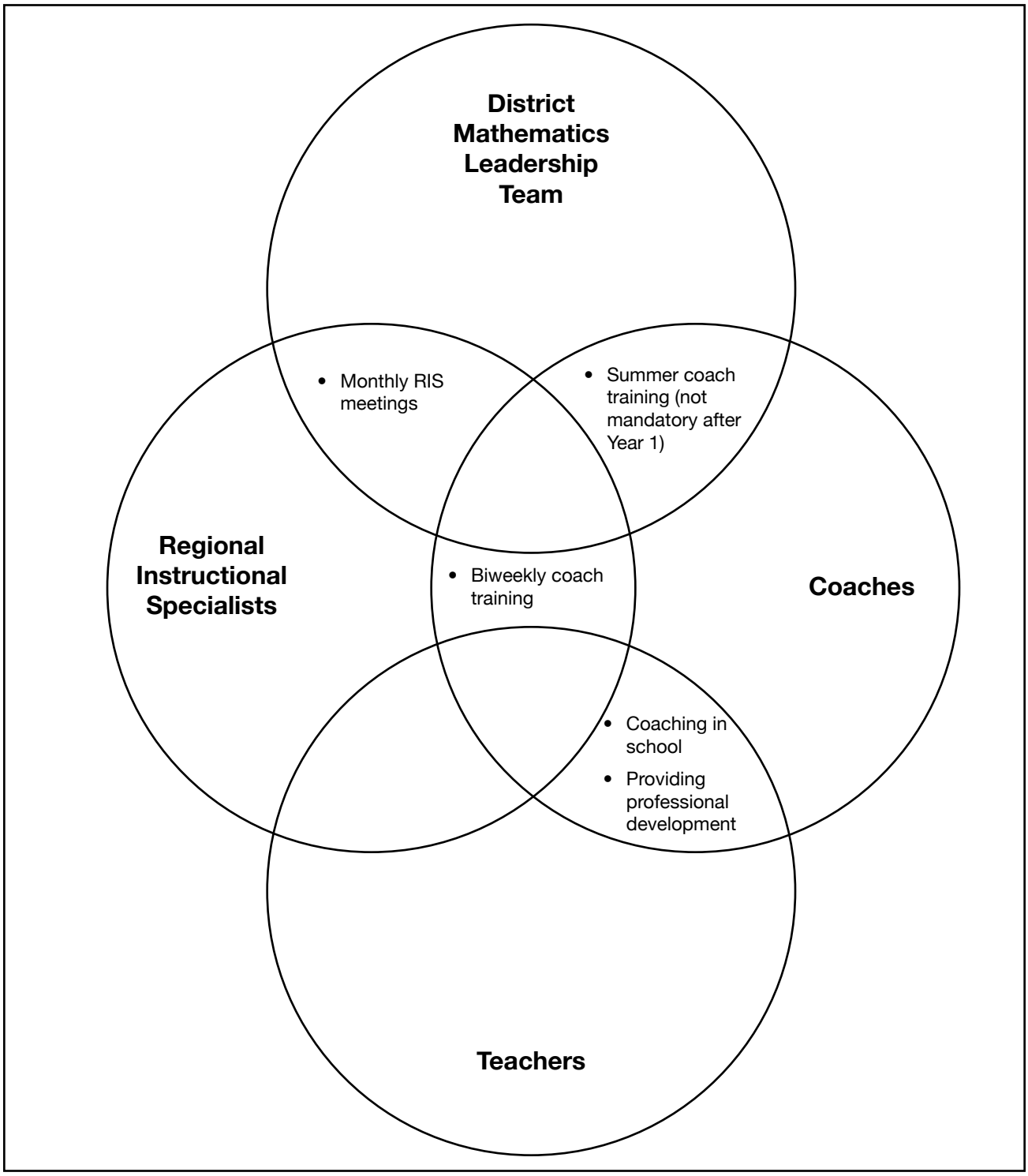
We begin with a comparative look at the districts' designs—that is, their "architectures"—for guiding and supporting professional learning. Here, despite many similarities, subtle differences in the learning architecture, in part reflecting contrasting conditions in these two settings, set the stage for substantial differences in the enactment of the learning system and its corresponding effects on teachers' learning.

New York City-Region X

With the onset of mayoral control and the appointment of Joel I. Klein as chancellor in 2003, the NYC public school system began a major transformation. In the summer of 2003, the entire New York City system was reorganized from 32 community school districts into 10 large regions, each of which was overseen by a regional superintendent. At the heart of this reorganization was a recognized need to move away from bureaucratic oversite to an emphasis on teaching and learning. Each region, it was argued, would become a "learning community." The emphasis on teaching and learning (vs. administrative roles) was further supported by new job titles. Regional superintendents were called Regional *Instructional* Superintendents, network leaders within each region were called Local *Instructional* Superintendents (LISs), and literacy and mathematics leaders within each region were called Regional *Instructional* Specialists (RISs). Within mathematics, this transformation was marked by the appointment of a new director of mathematics, the adoption of *Everyday Mathematics (EM)* as the district-wide curriculum,[5] the installation of mathematics coaches, and the creation of a variety of professional development opportunities for teachers and coaches. All elementary schools, with the exception of 200 so-called "waiver" schools were expected to participate in the new mathematics instructional program. In year one (2003-04), teachers in grades K-2 were expected to implement *EM*; in year two (2004-05), grades K-3 teachers would implement it, and finally, by the third year (2005-06), teachers in all grade levels (K-5) would be expected to be implementing *EM*.

The roll-out of *EM* was marked by a broad array of professional development. In order to keep everyone "on the same page," NYC system leaders designed a variety of boundary practices—occasions for individuals from different levels of the system to interact. Three primary groups of individuals were responsible for aligning learning across these levels: the central office mathematics leadership team, the regional instructional specialists or RISs (one elementary math RIS was assigned to each of the 10 regions), and coaches (one mathematics coach was assigned to each elementary school). Figure 1 identifies the boundary practices that lay at the intersections of these three groups and between these groups and teachers.

Figure 1. Boundary practices in Region X



In theory, regularly occurring events within the intersecting areas of Figure 1 represent opportunities for individuals at different levels of the system to engage in cross-community conversation. For example, the district mathematics leadership team engaged in boundary practices with the regional instructional specialists in all-day, monthly meetings (upper left intersection). District leaders' interactions with coaches occurred for one week in the summer (upper right intersection), but was mandatory only the first summer. Coaches were primarily connected to district leadership through their RIS (shown by

the small intersecting area between RISs and coaches in the middle of the diagram.) Finally, a teacher's primary link into this system of interlocking boundary practices was the coach assigned to his or her school (lower right intersection).[6]

Interviews with NYC district leaders revealed a second avenue for aligning professional learning across the district: the widespread use of the *Everyday Mathematics* curriculum materials and the creation and distribution of the *Comprehensive Approach to Balanced Mathematics* or *CAB*. *Everyday Mathematics* was, of course, their adopted K-6 curriculum which included a guide for teachers, student workbooks, and a teacher reference manual. Its ubiquitous use in the boundary practices noted on Figure 1 confirms its status as a boundary object—an artifact that, although interpreted and used differently by members of various communities helped to align leaders', RISs', coaches' and teachers' notions about the reform. The *CAB* was a pacing guide created by district leaders. It began with a brief introduction to the district's instructional approach (the Workshop Model[7]). The remainder of this thick, two-volume, 3-ringed binder was arranged by grade level and by lesson. For each day, it specified the lesson (page numbers in *EM*), the mathematical focus of the lesson, where the lesson fell in terms of monthly pacing guidelines, student workbook pages for in-class work, homework pages from *Math Steps*,[8] and how the lesson was aligned with the city scope and sequence and with the state standards. It, too, was referenced regularly during the boundary practices shown in Figure 1.

Our observations of district-led monthly RIS meetings suggest that the *intention* of these meetings was to encourage individuals to negotiate the meaning of *EM* and the *CAB* in ways that made sense for their communities and, in turn, the communities with which they were entrusted to work. For example, in the second RIS meeting of year one, one of the central office mathematics leaders acknowledged the necessity of district leaders reaching teachers and others in an indirect and mediated manner. "This [monthly RIS meeting] is *the* main venue that Central has for talking *through you* [the RISs] to coaches and teachers." She went on to discuss how the monthly meetings would fail if they became simple hand-offs of training materials to RISs who, in turn, simply handed them off to the coaches. Rather she said, "We have to go into it and really understand it together;" as such, she was acknowledging the need to negotiate the meaning of the boundary objects in ways that would allow the RISs, in turn, to meaningfully represent them to and discuss them with their coaches (November 2003 RIS meeting).

Similarly, our observations of RIS-coach interactions in Region X suggested the *intention* to strive for meaningful participation. Biweekly, full-day coach training (every other Friday) represented the opportunity for the Region X RIS to "broker" the information she had learned in the monthly district-led meetings to her coaches. During the first year of the reform, however, Region X's coach training was not always focused on the two primary boundary objects—the curriculum and the *CAB*. Rather, the RIS elected to introduce many of her own ideas about what was important for coaches to know and be able to do. Thus, in addition to using the sanctioned materials, she also exposed her coaches to new ways of thinking about and learning mathematics. For example, she spent some time during each session having coaches solve open-ended problem situations in pairs or small groups and then discussing their approaches together as a large group. She reported doing this in an attempt to help coaches develop the mathematical content knowledge that would, in turn, enable them to negotiate meanings of the district-led initiative in ways that were most sensible for them and their teachers. By end of the first year, however, she had begun to plan and deliver training that was much more centered on how to implement *EM*. This was at least partially in response to her coaches' request for training that would provide them

with expertise in how to use the *EM* materials. Speaking of the focus during the early coach training sessions on solving math problems, one coach said, "It's interesting once in a while to do that, but we really wanted more to get into the *EM*, the math behind *EM*, and things like that. So we were really asking for something different. We didn't really want to invent it [meaning they didn't want to invent strategies for solving problems] although it was interesting. We really wanted somebody who could tell us about *EM* and some of the things because we hadn't done [grades] 3, 4, and 5 before. So, they got people from *EM*" (meaning that consultants from *EM* conducted some of the coach training).

Coaches were expected, in turn, to broker information from the district, as mediated through their RIS, during their encounters with teachers and others in their home schools. These encounters include both working with individual teachers and holding bi-weekly after school professional development sessions for all of the teachers in the school.

In NYC's learning architecture, then, RISs and coaches—along with the *EM* curriculum itself and the *CAB*—were intended to serve as key links between the district and teachers. Three things stand out as noteworthy about the design of these connections. First, RISs were responsible for a large number of coaches. Each region comprised approximately 100 schools of which the majority were elementary schools. Thus, RISs were responsible for overseeing the work of nearly 100 elementary mathematics coaches. The challenge of this task was recognized by district leadership. As stated by one district leader: "I know that the big thing that I am hearing over and over that seems so difficult . . . is that a RIS is responsible for many, many schools, I think many of them feel many more schools than they could ever possibly get to." Indeed, the challenge of reaching all schools was a frequent lament of Region X's RIS. For example, during a planning meeting that occurred during the summer 2005 district-led coach training, she said that she didn't have high expectations of what her 77 coaches would be able to do as a result of the summer training. "As a RIS, I can't possibly get around to all the schools and coaches and so there is little accountability for coaches implementing what they learn in professional development."

Second, despite intentions to the contrary, most of the connections between communities were uni-directional, the underlying idea being the "turn-key model." As stated by the city-wide leader for elementary mathematics when asked about the design of support for the math reform, "The [central office leaders] would work with RISs and RISs would then essentially be the staff developers of the math coaches, who would then. . . . . it was sort of, kind of a turn-key, turn-key, turn-key kind of thinking. Coaches would then turnkey and work with their teachers."

Third, the entire cascading structure (central office math leadership to RISs to coaches to teachers) occurred outside the administrative line. Parallel to the cascading, interlocking boundary practices for mathematics that we have just described, was another set of interlocking boundary practices for administrators: the deputy chancellor worked with regional superintendents who, in turn, worked with local instructional superintendents who, in turn, worked with principals. However, few if any crossovers occurred between the two cascading structures. For example, the training of new, aspiring, and veteran principals throughout the city had been turned over to a new entity, the Leadership Academy, and the mathematics department had limited success obtaining significant blocks of time on the Leadership Academy's agendas for city-wide principal meetings. The NYC system had made some provisions for mathematics training for principals and assistant principals through Lehmen College's "NYC Mathematics Project." We observed two of these sessions, both of which were poorly attended and were

run by individuals who were not deeply familiar with the philosophy or procedures of *EM* use in the NYC system. Within Region X, the mathematics training of principals appeared to take a back seat to literacy training. According to the Region X RIS, although the regional superintendent held monthly principal meetings, only one (as of April 2004) had been devoted to mathematics, and it had been run by an external consulting group. Finally, within schools, no provision was made for leadership teams comprising of administrators and coaches; there was no dedicated time for meetings, nor did administrators and coaches receive training for how they might work together to carry out instructional improvement in the school.

Returning to the boundary practices represented in Figure 1, it is interesting to note that our observations of the practices that occurred within them converged—over time—into a remarkably similar image. There were early attempts during monthly district-led RIS meetings to engage participants in open-ended mathematics problems, watch videotapes of lessons and examine student work.[9] Similarly, as noted earlier, during the first year of the reform, the Region X RIS devoted time to having coaches work on open-ended mathematics problems. However, these kinds of activities decreased precipitously in the second year. By the second year, the leaders of boundary practices tended to use similar strategies to engage participants in focusing on the key boundary object—*Everyday Mathematics*. Most of the professional development we observed, whether it was meant for RISs, coaches, or teachers, engaged adults in learning how to *use* the *EM* materials or how to manage those materials with respect to typical challenges such as parental communications, grading, or teacher-expressed concerns. For example, typical topics of the all-day RIS meetings included making sense of *EM's* distinctions between Beginning, Developing, and Secure skills, bridging between *EM* assessments and city-wide report card structures, demonstrating how the games in *EM* should be used, and discussing issues related to the pacing guidelines. Similarly, the RIS-led professional development for coaches—in the second year—tended to focus on "how to use the materials." Finally, our observations of school-based professional development as well as teachers' comments about them suggest an emphasis on learning to navigate through the materials. For example, in one after-school professional development that we observed, the coach spent the entire 90 minutes leading teachers through the various parts of the *EM Assessment Handbook* and suggesting how they might use them.

The boundary practices also consistently focused on issues of coordination, especially using the *CAB* to assure coverage of city and state standards. Teachers consistently received the message that (a) they could not and should not skip any lessons; and that (b) they needed to keep up with the pacing schedule in the *CAB*. As stated by the city-wide Director of Mathematics: "They [the teachers] like the fact that we have said to them, 'If you follow this pacing [in the *CAB*] you will cover everything and we have checked it and double checked it for you.' I think they get a certain amount of comfort from that. . . . We basically say to people, 'Look, if you follow the pacing for the first year, you know, as you get to know the program, this will continue to get better.' Similarly, in the summer 2005 district-wide training for coaches, the session leader warned the coaches that teachers would want to jump around in the curriculum. She went on to warn coaches not to allow them to do that. "They must follow the pacing chart." After a few pointers to ways to use the *CAB*, the leader said, "Isn't that powerful?" The coaches responded with a resounding, "Yes!" (7/12/05).

Capital City School District

In Capital City School District, the vision for mathematic reform was similarly bold. In 2002, the district, under the direction of a new superintendent, appointed an elementary mathematics curriculum review committee and charged them with creating a "unified educational program" in mathematics. Before that there had been no district curriculum and the superintendent felt the need for coherence. They selected *Investigations in Data, Number and Space* and designed a roll-out beginning in Fall 2003 that expected all teachers to be using all modules of the curriculum within two years.

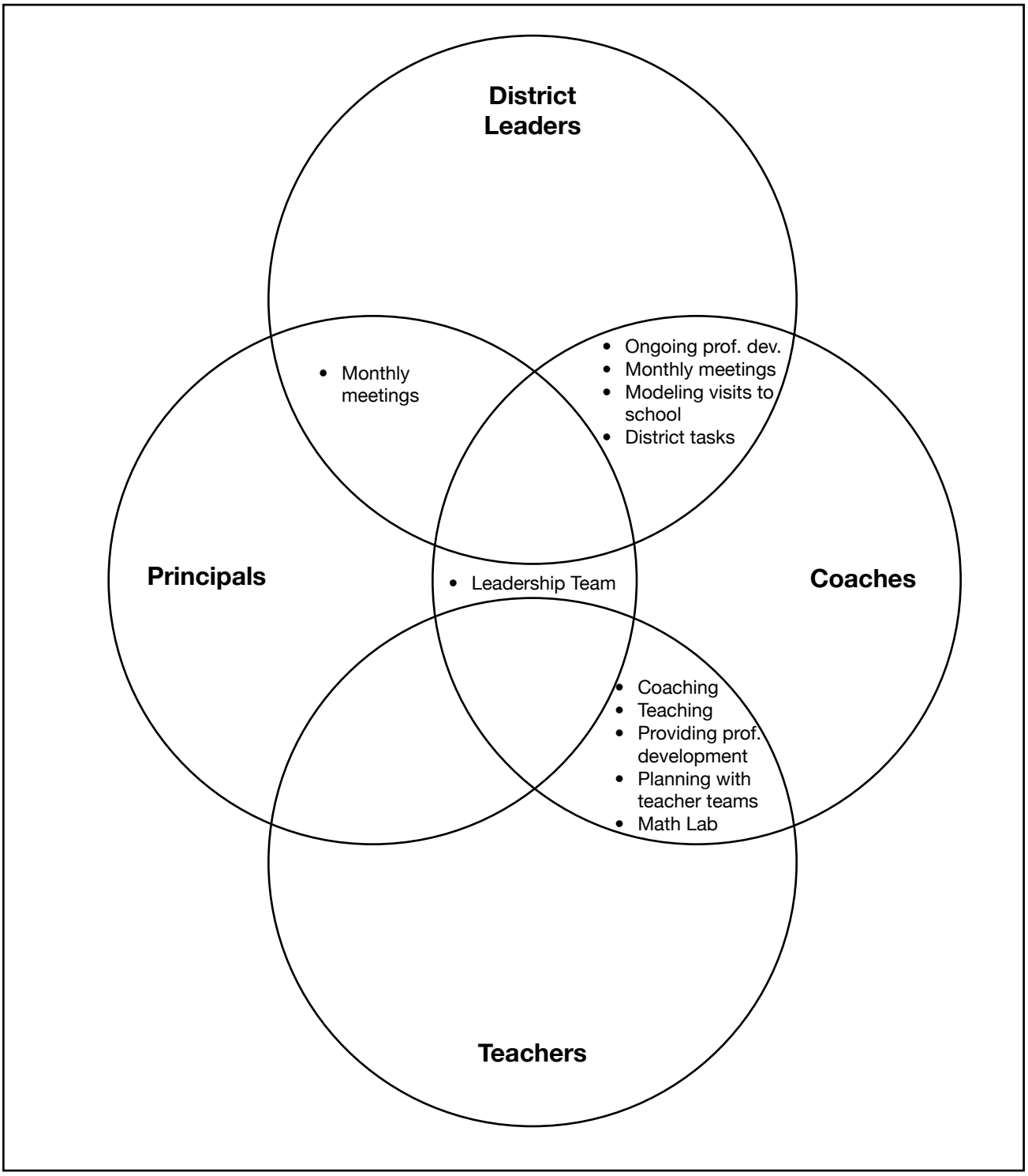
Similar to New York City, Capital City initiated a range of professional development to support teachers' and other professionals learning surrounding the new mathematics curriculum. These professional development experiences crossed levels of the system to involve nearly all individuals with instruction-related roles and to move teachers' classroom practice into alignment with the new district curriculum. Figure 2 illustrates the design of these boundary practices.

Similar to Region X, coaching represented a major way to link communities of practice in schools with district leaders. Unlike Region X where there was one full-time coach in each school, however, Capital City had two mathematics coaches per school, each of whom taught half time in their classroom and acted as a mathematics coach for the other half of their time. Coaches were connected to the district through participation in a series of professional development experiences, monthly meetings with the director of mathematics, and periodic visits to the school by the director of mathematics during which she coached the coaches as they worked with teachers. A smaller subset of the coaches also participated in district-level tasks such as serving on the curriculum adoption committee, creating the pacing guide, and developing and revising the district-wide formative assessments. Coaches, in turn, were connected to their schools through their participation with their school principals and assistant principals on the school leadership team and in their work coaching individual teachers, working with teacher teams on planning, and providing professional development on early release Thursdays once or twice a month.[10] Coaches also participated with a small number of teachers in the school during an event referred to as MathLab. During intersession, teams of teachers teach children in the morning using *Investigations* materials and then have professional development with coaches in the afternoon that helps them deepen their understanding of the curriculum and the mathematics that lies beneath it.

Like New York City, boundary objects also played a key role in aligning professional learning across the district. In this case, leaders turned to a trio of boundary objects: the adopted textbook (*Investigations*),[11] district-developed quarterly math assessments (QMAs), and a pacing guide (also referred to as the blueprint) meant to coordinate the textbook and the QMAs with each other and with state standards and assessment.

The district curriculum was organized by grade-level objectives that were linked to the state standards. *Investigations* was viewed as the program that was used to achieve those objectives; that is, it was viewed as a tool to meet the objectives/curriculum, not as the curriculum in and of itself. In addition, the district had developed the QMAs as a formative assessment tool to measure the extent to which students were meeting the objectives spelled out in the pacing guide and covered in the *Investigations* curriculum modules. This pacing guide had been gradually rolled out; it, too, placed primacy on the "objectives," then identifying which *Investigations* modules to use to achieve them, as well as providing suggested timeframes.

Figure 2. Boundary practices in Capital City



Thus, Capital City's learning architecture relied on coaches and a trio of boundary objects to serve as the key link between the district and teachers. The design of this link included several noteworthy features. First, there were a large number and wide variety of interlocking connections between the coaches and the district, on the one hand, and between the coaches and the school, on the other. Second, the linkages were bi-directional. Various boundary practices brought coaches up into the district to engage in district policy making around pacing schedules and QMAs; at the same time, other boundary

practices brought district policy makers into schools to provide support and professional development to coaches in the context of their local communities. Third, coaches were connected to the schools at the leadership level (through participation in the newly designed leadership team structure), the grade level (via grade level teams), and the individual teacher level (via in-class coaching).

In addition to the work with coaches, the district also created connections to the school leaders via their work with school leadership teams. First, the director of mathematics was provided time during monthly district-wide principal meetings to discuss *Investigations* and work with school leaders on issues of mathematics content and teacher learning. But the school leaders—principals and assistant principals—also participated in professional development as a team with their building coaches in leadership team trainings. The leadership team was a new organizational structure instituted in the schools during the first year of efforts to scale-up the new mathematics and literacy curricula. The principal, assistant principal, literacy coaches, and mathematics coaches were to meet weekly to discuss curriculum implementation and plan professional development. They also attended professional development for the leadership team together. These opportunities—which happened approximately twice a year—tended to be content- rather then management-focused. While a small portion of these meetings was typically devoted to issues of coordination, most of the time was spent focusing on mathematics and literacy teaching and learning.

These diverse boundary practices involving diverse actors in the system were similar in approach. They tended to use similar strategies to engage participants in using the key boundary objects—the textbook, the pacing guide, and the QMAs—as a way to develop approaches to instruction rooted in understanding of the mathematical content and careful attention to the nature of student thinking. Nearly all of the professional development we observed, whether it was coach professional development, leadership team professional development, MathLab or grade-level planning meetings, engaged adults in doing mathematics problems together (usually from the *Investigations* curriculum) and explicitly discussing the nature of the mathematics involved in the problem. A common refrain heard from the director of mathematics when working on mathematical problems was "What is the mathematics here?" They also frequently involved adults working together to look at student work and identifying the kinds of mathematical thinking evidenced in the work.

The boundary practices also focused on issues of coordination and alignment, especially using the reifications to coordinate instruction with state standards and assessments. For example, coaches were encouraged to use grade level planning meetings to examine the objectives on the pacing guides and the QMAs to focus on ways to use the curriculum to meet the state objectives as measured by the QMAs. And indeed, particularly at the school level, much discussion in grade-level meetings focused on this coordination. However, coaches and leadership team members were also encouraged to work on these tasks in ways that did not lose sight of the mathematics and student learning at the center of the curriculum. For example, the director of mathematics repeatedly emphasized using the pacing guides to link the state objectives with the particular *Investigations* unit as a way of focusing on the nature of the mathematics involved in the unit. Some coaches and school leaders argued that QMAs should be used as a window into the kinds of strategies students were using to solve problems so that teachers could draw on that information in order to plan next steps in instruction.

In summary, there were both similarities and differences between New York City's and Capital City's architectures for learning. Both relied on a combination of boundary practices and boundary objects, including the curriculum itself and a pacing guide. New York's architecture was more complex, however, because leaders had an extra level to design for: the hand off from central office to regional instructional specialists. New York's approach appeared to be more uni-directional and exclusive to mathematics specialists whereas Capital City provided opportunities for two-way influence and included the administrative line in substantive ways. Finally, while both districts attended to issues of coordination and management, Capital City—more so than New York—balanced attention to coordination/management with a strong focus on mathematical content.

The Lived Local Communities

Despite the importance of district leaders' designs for learning—and even their enactments in the upper layers of the cascade (e.g., boundary practices between district leaders and coaches)—it is the nature of meaning making within and between "lived" communities that dictates how such reforms do or do not take hold in the classroom. Thus, we begin by asking: How—during the early years of reform—were teachers and other professionals close to the classroom interacting to make meaning of these changes?

New York City-Region X

Looking across the two schools in our study sample, we first establish who was interacting with whom about mathematics (in order to identify the relevant communities of practice surrounding mathematics that existed). We then characterize the nature of their interactions with respect to the mathematics reform in these communities.

Teachers interacting with teachers. The degree to which teachers had developed identifiable communities of practice surrounding mathematics was limited in the two schools that were studied. Teachers in Lincoln interacted around mathematics instruction almost exclusively with colleagues in their grade level teams. All but one of the six focal teachers reported that they interacted at least weekly with their grade level colleagues and one of these teachers also interacted occasionally with colleagues at other grade levels. However, interaction in Lincoln was largely focused on managing the curriculum and keeping pace with other colleagues in their grade. For example, one teacher explained that she talks with her colleagues about "anything that we need to cover." Another described a recent interaction: "We compare notes and see how far we have gotten. We are generally going at the same pace which makes me feel good that I am not either underestimating or overestimating what my students are capable of." Overall, 37 percent of the interactions we observed or heard about were about pacing or coordinating materials. This figure is a bit misleading, however, because one teacher in Lincoln deviated from this pattern and most of her interactions were more substantive. Without this teacher, the percentage of interactions focused on pacing and materials in this school rises to 75 percent. Only three out of the six focal teachers reported discussing specific instructional strategies and only one of those teachers went beyond superficial conversations about which strategies worked and which did not.

In Marshall, teachers were more likely to interact around mathematics with colleagues in multiple grade levels. However, with the exception of the two teachers in kindergarten who talked with one another about mathematics nearly every day, teachers in Marshall reported that they interacted infrequently with their colleagues about mathematics. Most of this interaction occurred at lunchtime and was focused on coordinating pacing within grade level. Fifty-one percent of interactions that we observed or heard about were focused on where teachers were in the textbook. There were some conversations about instructional strategies, but, as was the case in the first school, these conversations tended to be quite superficial. For example, a first-grade teacher characterized lunchtime conversations as, "You know, we share ideas." Another teacher said, "We just swap ideas, exchange ideas." Some of the specific ideas that were mentioned included using food for a lesson on patterns, using "the grouchy ladybug" to teach time, and teaching children who are having difficulty with tally marks, to say "chop, chop, chop, chop, suey!" as they write the first, second, third, fourth, and fifth tally mark for representing a group of five. It is also important to note that as teachers made meaning of the textbook in their lived communities, many came to the conclusion that the series was inappropriate for their students or that they were better off skipping or replacing particular activities or approaches they did not feel would work in the classroom. For example, one teacher described her interaction with her grade level colleagues in the following way: "We agree upon a lot of things [about the curriculum]. Basically: the inconsistencies. One teacher in particular doesn't really care much for the program at all. So we try to touch on the concepts, but not really follow it." Another teacher explained: "To be honest with you, [my grade level colleagues] think it blows. They don't like it at all." In this school, nearly 40 percent of interactions among teachers that we observed or heard about involved discussions about how to adjust, adapt, or ignore aspects of the curricula in ways that were not aligned with the recommended implementation promoted by the district.

Coaches interacting with teachers. The coach was part of teachers' lived community for nearly all focal teachers in both schools. However, there were differences within and between schools in the frequency and quality of this interaction. For example, in Lincoln, the coach worked intensively with upper grades teachers, who reported that they talked with him at least once a week. With one exception, lower grades teachers reported much less frequent interaction. In contrast, none of the teachers in Marshall reported interacting with the coach in more than an occasional fashion.

There were also differences in the nature of interaction between teachers and coaches in the two schools. Teachers in Lincoln perceived the coach as being very helpful. As expressed by one teacher, "He [the coach] has been a great resource for me. He's been in the room quite often this year working with me, to help me learn this program." Interaction between this coach and teachers mainly focused on managing the different parts of the curriculum and linking them with other policy documents such as the pacing guide. For example, one teacher described a typical interaction with the coach in the following way:

> We talked about the Math Message and the Mental Math (two components of every *EM* lesson) and how to coordinate between the two and that we should be linking the Math Message to the initial onset of the mini-lesson [the first phase of the Workshop Model] and how those two are connected . . . That's something I'd like to get straight. Because the Teacher's Guide is a bit fuzzy about that, I thought. It was a bit misleading when it came to the Math Message and the Mental Math. So, he with his training, was able to tell me that I should teach it in that sequence.

Other teachers noted that the coach would help them procure materials needed for particular lessons (e.g., tape measures, manipulatives) and would demonstrate particular instructional techniques. Noticeably absent from any of the reports of conversations, however, was meaningful discussion of mathematical content or student thinking.

In Marshall, coach-teacher interactions appeared to consist of the coach telling the teachers to look things up in the pacing guide or the *EM* teachers' manual. For example, one teacher described a conversation she had after she missed a district-offered professional development on the new curriculum: 'So, I asked the math coach, I said 'Well, what are we supposed to be doing?' He said, 'Well read the manual.'" This coach rarely demonstrated or observed lessons (only two teachers reported such experiences, each only one time) and conversations with teachers about instructional techniques were both relatively rare and tended to be fairly superficial. For example, one teacher described her attempt to get advice on how to help her second graders do a two-digit addition problem: "He feels like the lesson was the eighty-two plus eighty-three plus eighty-four…he's like, 'they should be able to do it in their head.' I'm like 'it ain't happening.'"

Principals interacting with teachers & coaches. Only two teachers in each school cited the principal as someone who they interacted with around mathematics instruction. Most of this interaction consisted of providing materials or test data. This may be related to the fact that neither principal has been trained in mathematics and neither the principals nor the teachers saw the principals as possessing expertise in mathematics.

There was, however, more interaction between coaches and principals in Lincoln than in Marshall. The Lincoln principal reported relying on the coach for "everything related to mathematics." The coach reported that most of his interactions with the principal centered on two functions: identifying ahead of time the topics that the principal *should* expect to see when observing in classrooms, and helping the principal interpret things that she had questions about. When asked for examples, the coach said, "I'd tell the principal that second grade is on "introducing fractions" this week." Overall, these conversations appeared to include limited discussion of mathematical content or student thinking.

However, there was little interaction between the coach and the principal in Marshall. The coach indicated that he consults with the principal about the math displays that are in the hallways in the school building and identifying topics to be covered in after-school professional development sessions. The principal did not, however, mention the coach as someone she goes to when she has a question or issue related to mathematics.

Cross-school communities. Very few individuals in the two NY schools participated in cross-school communities. Only three teachers in Lincoln and one teacher in Marshall reported that they talked with even one person outside of the school about mathematics. Three out of the four talked with a relative about mathematics; for example, one teacher in the second school had frequent conversations with her mother, a retired public school teacher, about the new mathematics curriculum. Two of the four talked with someone in the district office about mathematics, but only did so rarely.

Both principals reported that they talked with their supervisors in the administrative hierarchy about mathematics. One also mentioned occasionally calling a principal from a neighboring school to get advice about a broad range of problems, sometimes math-related sometimes not. The math coaches in both schools also referred to their immediate supervisor, but they also referred to coaches from other

schools that they interacted with at weekly coach meetings run by the district. This interaction mainly consisted of sharing strategies for working with teachers and, occasionally, getting advice about how to do particular units. For example, one coach described his interaction with other coaches at bi-weekly coach professional development in the following way: "We have the opportunity to plan for demonstration lessons…we would sit as a group of coaches at a table like this and discuss a second grade lesson or a fourth grade lesson and ask for advice from other coaches and so forth." Overall, though, principals and coaches rarely if ever reached out beyond designed district-designed role relationships. There was little mention of informal contacts, e-mail exchanges, or any other form of on-going communication.

Capital City School District

We now turn to the Capital City School District in the southwest. As with Region X, we begin by establishing who was interacting with whom about mathematics and then characterize the nature of the conversation that occurred within these interactions.

Teachers interacting with teachers. Although there were some differences within and between the two Capital City schools, teachers' lived mathematics communities tended to be more widespread, involve more frequent interaction, and involve more in-depth and congruent conversations about mathematics than those in the two New York schools.

Across both Capital City schools, most teachers (8 out of 12) reported that they interacted about mathematics with teachers in multiple grade levels at their school. Nearly all teachers (10 out of 12) reported that they had daily or weekly interactions with most of the individuals they identified. But the main difference between teachers in the Capital and City and New York schools was the content and depth of interaction. While most of the teachers' interactions in New York focused on managing the curriculum and keeping pace with colleagues, these conversations, while present, played less of a role in Capital City schools. For example, only 22 percent of the interactions that we observed or heard about in Trafford Elementary School and 42 percent of Bakersfield Elementary School were focused on these issues (compared to 51 percent and 75 percent in the two New York City schools). Thus, 88 percent of interaction in Trafford and 58 percent in Bakersfield was focused on instructional strategies, student learning, and the nature of mathematics. For example, one teacher described a recent conversation with a grade-level colleague focused on student learning: "We bring some story problems that the kids are working on and really look at how their [problem solving] strategies are working and what strategies we need to maybe focus on or where we need to move the students from where they are now." Another described a conversation that touched on the mathematical content of the lesson: "I was speaking to [another teacher] yesterday after school and I was asking her, what does it mean if they don't understand that—it was the identity property. Zero plus a one is zero. What does that mean? What am I supposed to do with that? Where do I go from here? And we were determining that it's just not appropriate for them right now."

Finally, most teachers in both schools had conversations that were predominantly congruent with the intent of the curriculum. In eighty-nine percent of interactions we observed or heard about in Trafford and eighty-two percent of interactions in Bakersfield, teachers were making meaning of the curriculum in ways that were consistent with the approach advocated by the district. One exception was a fourth grade teacher in Bakersfield who reported that her colleagues were very opposed to *Investigations*. She explained: "Our fourth grade team—I'm really the only one that is really doing the program the way

it's supposed to be…if I'm talking to people that are on my grade level, it's fighting or trying to stick up for the program." As a consequence of this dynamic, this teacher reported that she rarely interacted with her grade level colleagues, turning instead to those in a neighboring grade and the coach, who she reported was "my best ally" in supporting her use of the curriculum.

Teachers interacting with coaches. Both Capital City schools had two mathematics coaches, each of whom was a half-time teacher and half-time coach. These coaches played an important role in *teacher* professional communities in the two schools. As was the case in NY, every teacher mentioned one or both of the coaches as people they went to when they wanted to talk about mathematics. However, the nature and frequency of these conversations varied greatly between Capital City and New York schools. First, although there were some differences between the two Capital City schools, teachers in Capital City generally reported more frequent interaction with the coaches than in New York. Furthermore, some of this interaction occurred outside the formal coaching structures (one-on-one coaching and team meetings) as teachers reported reaching out to coaches informally on their own or in groups to talk about mathematics. For example, one teacher explained: "[The coach] comes in once a week and observes…But she is definitely a resource that I go to all the time. I actually used her today after you left... I always use my math coach, even at the end of the day when I am planning or if I get stuck and don't know where to go or how to move my kids to the next level, I always use her for support."

The more striking difference between New York and Capital City, however, can be found in the nature of coach-teacher interaction. While most coach-teacher interaction in New York was focused on managing the curriculum and sharing instructional strategies in a superficial manner, coach-teacher interaction in the two Capital City schools, while including some of this talk, extended beyond it to include more in-depth conversations about instructional strategies, discussions about the nature of student learning, and, at times, the nature of mathematics itself. For example, when asked what she talks informally to her coach about, one teacher in Trafford said:

> I have so many kids that can't count past six or seven, what is wrong? What am I doing wrong? That, I can take to my coaches and say: "Look, this is what I've noticed. This is what I've done for instruction. Do you have any advice? What do you think it might be? How can I do this or approach this differently to help these other kids that aren't getting this concept?"

Similarly, a teacher in Bakersfield also described the kind of in-depth conversations that she has with her coach about teaching and learning:

> Like right now I'm still working on assessment. How can I assess while they're working? How do I do that? And so my coach, she's looked through articles for me. She finds articles about how to group the kids and still pull small groups. And, we'll talk about these articles and figure out how to make that work in my classroom.

Across the two schools, four teachers also described interactions with their coach where they discussed a mathematical concept or principle. For example, one teacher explained: "I actually used her today…to ask her some questions on some of the triangles and how the angles relate to one another."

Also, interestingly, across both schools, we found some teachers who see their interactions with coaches as a way to influence the district. Coaches are not just seen as providing information from the district about issues of implementation, but as a way to get information back up to the district. In discussing a problem that one grade level group discovered with the quarterly assessments, one teacher described the following:

Interviewer: Do you have any way of giving this feedback to the district?

Teacher: We do, we do. We talked to our coach and she took it back to the—you know—her peers among other coaches. She's actually involved in writing the next quarterly math assessment for [our grade level] at the district.

Principals interacting with teachers & coaches. As in NY, few teachers included principals as part of their mathematics communities. Only three teachers in Trafford and two in Bakersfield reported going to their principal to talk about mathematics instruction. However, in contrast with NY, both schools had much more robust interaction between principals and coaches. Each school has a designated (i.e., formal) leadership team comprising principals and mathematics and literacy coaches. In both schools, this leadership team has emerged as a consequential community of practice (although to a lesser extent in one of the schools). When asked who they seek out to talk about mathematics, principals nominated coaches and coaches nominated principals. One coach described the relationship in the following way: "Generally, sometimes, [the principal] will just pull us in to talk about, 'OK, we want to do this for math' or 'what do you think the next direction is?' She doesn't always say, 'do this.' She does ask a lot for 'look at our data, what do you think?' There is a lot of that going on." Interestingly, there was also quite a bit of dialogue between literacy and mathematics coaches. This conversation was both about getting advice about coaching strategies, but also about the connections between literacy and mathematics.

Cross-school communities. One of the things that is striking in Capital City is the degree to which individuals have forged cross-school communities. This is most evident among the coaches. When asked who they seek out to talk about instruction, coaches not only nominated individuals in their schools, they also consistently nominated coaches at other schools and one or two people at the district level. Three out of the four coaches at the two schools also reached out beyond designed district-wide coaching meetings to contact one another on a quite frequent and consistent basis: As one coach said, "We spend a lot of time talking about math. I talked to [five other coaches, listed by name] about things and concerns a lot…I get a lot of e-mails back and forth from them about that type of stuff, so I tend to talk to them a lot, I would say."

Coaches, across schools, had rich and deep conversations with one another about the nature of mathematics and the development of student thinking. Our research produced many examples of this. When asked to describe an example of what she talked with other coaches about, one coach provided the following:

> In second grade…there are stringing problems, for like two plus four plus seven plus six. The kids are doing a little stringing. They call it the pull-down method…So they do those, but in the third grade when they start doing the two digit, the kids are still doing the pull-down kind of deal but they are not keeping the place value. You see that in subtraction too. We really see it in subtraction. They are using it just like an algorithm. . . . So they are just following a different algorithm with really no thinking . . . It is a misconception that in the teacher implementation of it something went haywire because the kids aren't understanding what they're doing. They are applying things they shouldn't be doing. I talked to people like [coach at another school] or [second coach at another school] "What do you see at your school? Are you seeing the same thing?" We had a nice discussion about the stringing, but oh my gosh, I'm so tired of seeing that. It's all over the place. They don't have the place value!

Another example:

> We met last week in my room and I was talking. We had written down things that [a professional developer from a recent training] had said like, "We do too much about

> pattern and not enough about structure in mathematics." That really spoke to me, so I asked [the others] "What are you thinking about that? Tell me." So we have more theoretical discussions. We have almost moved past, "how do you handle these people [teachers they coach]? How do you get them to do this?" We are talking about "What exactly is it the kids know and when do they know it? How do you know they know it?"

The coaches also talked a lot about specific grade level issues (nature of mathematics in kindergarten, for example) and can identify which coach in which school has expertise in which grade level. They also get a lot of advice about working with particular teachers, although, as the quote above attests, by the second year of coaching, they were no longer talking about this to the same degree. As interesting perhaps is what they don't talk about: how to use the curriculum and issues of coordination and management.

Principals and teachers also had greater cross-school interaction in Capital City than New York, although there was still some variability between the two schools. In Trafford, the principal reported that she not only reached out and had on-going conversations with multiple other principals in the district about mathematics, she also was in frequent contact with at least three district leaders representing mathematics, assessment, and technology. The principal of Bakersfield—who was not as supportive of the *Investigations* curriculum—reported that she had frequent and on-going conversations with several principals in the district, but did not interact with district mathematics leadership because "my philosophy is a little bit different [from theirs]." Fully half of the teachers in both schools had connections with others outside of the schools. Most of these teachers had multiple connections (4 out of 6) and all but one were with people at the district or coaches at other schools. Neither principal nor teacher connections to people outside the school were as frequent or deep as those of the coaches. But, with the exception of the principal of the second school, they were predominantly congruent with the intent of the curriculum.

In summary, there were important contrasts in the local, lived communities that were studied in NYC-Region X vs. Capital City. Across all four schools, coaches appeared to play an important role in teachers' lives. Every teacher in the four schools identified their mathematics coach as a person who they sought out when they wanted to talk about something related to mathematics. The interactions between coaches and teachers appeared to happen primarily during formal, structured events. However, we also saw evidence of teachers seeking out coaches and interacting with them in additional settings in the Capital City schools, suggesting that formal roles had transformed into authentic relationships in the context of lived communities.

Despite the importance of coaches across the four schools, what was talked about in the lived encounters between teachers and coaches differed in NYC-Region X vs. Capital City. In Capital City, despite some differences between the two schools, the interactions appear to involve a mix of business/coordination issues and serious focus on mathematics teaching and learning. In NYC-Region X, on the other hand, the one coach who did play an active and teacher-perceived helpful role, primarily focused on how to manage the *EM* materials, gathering manipulatives and other tools for teachers, and providing general "pointers" regarding how to plan for and teach a lesson. There was little to no mention of mathematical content or student thinking.

Teachers' interactions with one another were less robust than teacher-coach interaction in most cases. However, interaction in teacher communities in Capital City were more frequent, were more likely to stretch across grade levels, and more likely to move beyond pacing and managing materials to also include more depthful conversations about instructional strategies, student learning, and, at times, the mathematics itself.

Another difference across Region X and Capital City was the extent to which coaches appeared to form an authentic, "lived' community across schools. In Capital City, coaches often sought each other out outside of formal meetings; their conversations usually focused on substantive issues surrounding mathematics and how it is best taught and learned. In Region X, we saw no evidence of this. Finally, Capital City and Region X also differed with respect to the extent to which principals were an important part of various lived communities. In both Capital City and NYC-Region X, we saw little evidence of teachers interacting with principals around mathematics; rather administrators in both systems appeared to engage with the mathematics reform through their interactions with the mathematics coaches. However, the nature of principal-coach interactions differed across the two districts. In Capital City, coaches and principals took on substantive issues related to how best to carry out mathematics reform in their various schools; in Region X the relationship was defined by a division of responsibility with the principal turning over the "worry" of the math program to the coach.

Summary and Implications

In this paper, we have examined the approaches used by two districts to steer the roll-out of district elementary reform. In particular, we have focused on processes of alignment, that is, on how connections were formed between teacher communities and other district communities in terms of reifications and participation. We have found the designed and the lived experiences in the two research sites to be quite different. Why, despite good intentions, did Region X's efforts not lead to meaningful investment of teachers' energies, thoughts, and actions surrounding the teaching and learning of mathematics? Why did the boundary practices and reifications in Capital City, on the other hand, appear to invite participation and productive meaning making around these issues? In this concluding section, we attempt to answer these questions.

The first plausible explanation relates to the overwhelming difference in size between the two research sites. We have already alluded to how NYC's RIS-coach ratio was associated with a predominance of large-group boundary encounters and fewer individual, face-to-face meetings, occasions not ripe for a deep investment in participation and meaning making. This unwieldy connection between RISs and coaches can be viewed as a "vulnerable link" between district policy makers and teachers, with all downstream connections perhaps receiving less access to meaningful participation. However, the size of NYC also had implications for ideas traveling upstream to district policy makers. In large systems, good ideas have a more difficult time being noticed and bubbling up to the attention of leaders at the top. This, in turn, may be related to the fact that the NYC coaches did not engage in bi-directional communication, as did the Capital City coaches who even appeared, at times, to be creating district policy, as when they authored parts of the QMA and pacing guides.

The second plausible explanation that will occur to many readers is that the participation of administrators was different across the two research sites. Indeed in Capital City, administrators were knowledgeable participants in many decisions surrounding the mathematics program; this investment, more often than not, brought allegiance and support for the mathematics program. In NYC, on the other hand, principals seldom used the boundary objects and had few, if any, opportunities to participate in the negotiation of meaning surrounding them. Not surprisingly, the NYC principals appeared at times to not highly value the mathematics program, as when, for example, they complained about the time staff spent out of the building for math-related training or when they tap their math coaches to do non-mathematics work in the school. In Capital City, on the other hand, there have been explicit discussions within the school leadership team about the necessity of keeping the math coach role focused on teaching and learning in mathematics.

Another explanation lay in the history of the two districts. NYC-Region X was formed of three community school districts in Brooklyn. The scale-up of the math program coincided with this organizational restructuring and many individuals were slowly becoming accustomed to new colleagues and bureaucratic units. This was particularly challenging in mathematics because one of the old community school districts had previously implemented a progressive curriculum while the other two were using traditional textbooks. Capital City, on the other hand, was able to build on a previous history of practice with respect to the teaching and learning of mathematics. In fact, the inter-school coaching community referred to earlier was actually built prior to the relatively recent efforts to scale-up the new curriculum. A core group of veteran teachers in the district participated in 180 hours of professional development on Cognitively Guided Instruction through an Urban Systemic Initiative grant. Those teachers developed a community united in talking deeply about mathematics, especially mathematical content. Many of these teachers were then tapped first to serve on the adoption committee and then to serve as coaches in their schools. So it appears that rather than designed professional development encouraging the development of a lived community, the designed community tapped into and extended a pre-existing community.

Another explanation for the differences between Capital City and Region X might center on the messages that teachers and coaches received from their respective district leadership teams about the degree of flexibility surrounding their implementation of the curricula. Wenger refers to the range of meaning that individuals are permitted to make of boundary objects (such as the curriculum) as "negotiability." Messages in Region X and Capital City differed with respect to what was negotiable and to what extent. In Capital City, the main message was that teachers were supposed to use *Investigations* as the central mechanism for instruction. All previous textbooks were collected and teachers were told not to use any supplemental materials.[12] However, this message sat side-by-side with messages about the importance of careful attention to student thinking and learning as a central part of instructional decision making in the classroom.[13] Teachers were encouraged to adjust their instruction—both within a lesson and in the overall trajectory of instruction—based on evidence of student learning. Thus, it seems that teachers were encouraged to make their own meaning of the curriculum in collaboration with their coach and grade-level colleagues at the level of instructional decision making, but they were not encouraged to have discretion in using the particular materials. In Region X, teachers were also given the message that they were supposed to use the district's sanctioned curriculum (*Everyday Mathematics* supplemented by *Math Steps*) as their central mechanism for instruction. However, there was no companion message

encouraging them to use professional discretion to adjust or tailor their instructional practices within lessons based on their assessment of student thinking. In fact, quite the opposite, teachers were encouraged to keep up the pace, to keep progressing through the book despite the fact that not all students were mastering the objectives of the lesson (see earlier discussion about Beginning, Developing and Secure goals).

All of the above explanations are surely at least partially correct. However, returning to Wenger's central premise regarding the kinds of learning that are inspired under different forms of alignment, we propose that the differences between Region X and Capital City can also be explained by differences in how they integrated reification and participation. In New York City, both the architectural design for learning and interactions in the lived communities relied a great deal on heavily specified boundary objects; the participation surrounding those boundary objects was focused on issues of coordination and management, not issues of teaching and learning mathematics. In Capital City, the boundary objects also commanded attention, but they did so as foci around which more productive and teaching-and-learning centered negotiations occurred.

When discussing designs for learning, Wenger contends that different reifications provide different affordances for the negotiation of meaning. All designers, he argues, must confront decisions regarding what to reify, when, and in what form. Designers also have to make decisions surrounding participation. These involve getting the right people in the right place at the right time and in the right relation to one another and to key reifications. The challenge for design is to not overly reify, that is, to not specify so much in advance that there is little room for participants to design aspects of their own learning. Rather than doing away with such "emergent" aspects of design, the trick, according to Wenger, is to include them, to anticipate them and see them as opportunities for meaningful learning. This approach to design can be contrasted with front-loading a heavy dose of specificity. Such highly specified designs, Wenger argues, come with a certain amount of rigidity, rigidity that can actually work against individuals re-designing for the particular case with which they are confronted.

The two key boundary objects with which the Capital City and Region X were working were very different in this regard. *Investigations* provides a set of open-ended activities for teachers and students to engage in, along with information about the big mathematical ideas at play in the activities and ways in which students might respond to those activities. However, it does not script the teaching and learning that should occur, believing that learning is always an emergent phenomenon, one that teachers must be attuned to through their attention to student thinking (Russell, Economopoulos, Murray, Mokros, & Goodrow, 1998). Thus, while helping teachers to anticipate what students might do and need, the *Investigations* curriculum does not specify a specific teaching and learning route to follow. Moreover, by identifying the big mathematical idea at play (and even providing a brief tutorial on it), the materials allow teachers to apprehend the purpose of the activities; armed with this knowledge and information about possible student responses, there is the possibility that, with the right support, they can become "designers of instruction."

Everyday Mathematics, on the other hand, is divided into a series of daily lessons, each of which teaches to a fairly narrow objective. The tasks are much less open-ended than *Investigations* tasks and tend to channel students and teachers toward a particular route through the problem.[14] Teachers are provided with few in-depth details regarding how students might be expected to respond to the prob-

lems. There is, however, very detailed guidance on how to set up activities, what questions to ask, and what problems to give for reinforcement and follow-up. In general, however, there is little room for learning as an emergent phenomenon.[15]

This suggests that the nature of the boundary objects used by district leaders matters. Some boundary objects provide multiple openings for the negotiation of meaning while others provide fewer. Accordingly, when designing for participation surrounding one's selected boundary objects, district leaders will be constrained by what a particular reification affords. As such, we propose that another explanation for the differences observed in New York City and Capital City is the nature of the boundary objects that served as points of focus for the negotiation of meaning within the boundary practices. *EM* provided few openings for RISs, coaches, principal, or teachers to negotiate the meaning that the reform would have for their practices. As such, their participation—be it within or between communities—was often reduced to figuring out the "right way to do it" and how to coordinate the non-negotiables of teaching the curriculum with other teaching tasks (e.g., report cards, assessments, etc.) For example, during a Fall 2003 meeting, district leaders asked RISs to collect student work from grades 1-5, units 1, 2, and 3 before the next monthly meeting. The RISs were told to ask their coaches to ask teachers to select 10 pieces of "really interesting" student work. At the next meeting, very few pieces of student work were turned in. When asked why they had not brought student work to the meeting, the RISs' stated that collecting "interesting" student work was challenging because *EM* units (at least the units that teachers were currently working in) did not have the potential to produce anything very rich in the way of student work. The Region X RIS noted that she felt the need to infuse authentic student work into curricular tasks because "the majority of *EM* journal pages do not allow you to go deeper into the thought process."

Investigations, on the other hand, provided ample openings for individuals to negotiate meaning both within and across communities. For district leaders and coaches, the curriculum provided many rich tasks that served as fodder for engaging teachers in mathematics teaching and learning during boundary practices. For teachers, the curriculum provided many opportunities to negotiate meaning about the very thing for which they are responsible and arguably care most about: the design of teaching and learning in their own classroom. Thus, in Capital City participation was richer, focusing on the concepts that students were learning and how they were learning them. This kind of participation, according to Wenger, is more desirable because it allows teachers to adjust their practice when confronted with particular classroom and student scenarios..

In sum, reification and participation are two complementary aspects of design that create two kinds of affordances for aligned learning (Wenger, p. 231): (a) getting boundary objects in place so that practice at various levels has to be organized around them; and (b) getting the right people to interact to make something happen. Designs (or architectures) for learning are not recipes: they cannot infallibly produce learning that is aligned across an organization. Rather, Wenger argues, architectures for learning represent a set of choices surrounding the *distribution of reification and participation*. Good designs, we argue, are those that strike a balance between reification and participation—a balance that allows for negotiation of meaning surrounding features of practice about which participants care and are knowledgeable while still keeping the entire organization moving toward shared, recognizable goals.

* * * * * * * * * * * *

Returning to the question with which we began—How can districts create architectures for teacher learning?—we feel that we've advanced our understanding along a number of fronts. First, our findings suggest that learning architectures cannot be viewed as blueprints, but rather must leave room for negotiation. If the negotiation of meaning is how individuals learn within communities of practice, then designers must create or select boundary objects with this negotiation in mind. Rather than designing boundary objects for individual use, they need to design them for use within the various forms of participation they will encounter as they make their way across the boundaries of different communities and as they become "points of focus" around which meaning is made within communities of practice.

Second, alignment becomes trickier as the number of boundaries that must be crossed increases. In Capital City, coaches were the primary brokers between district leadership and school-based communities. In New York City, on the other hand, both RISs *and* coaches acted as brokers between district leadership and school-based communities. Thus, compared to Capital City, there was an additional layer of brokers (the RISs) in the design. This layer also happened to be the most "stretched" layer in the system of interlocking boundary practices; one RIS was expected to develop a regular, consistent practice with approximately 100 school-based coaches. The magnitude of the task meant that RISs seldom interacted individually with coaches in their home schools; most boundary practices were large-group, pull-out sessions that limited authentic participation and the negotiation of meaning.

Third, alignment can be enhanced when attention is paid to all the communities of practice that will have some say in how boundary objects will be interpreted. In schools, principals—as well as coaches and teachers—have a voice in what gets taught and how. Thus, they have some input into how boundary objects such as curricula are construed. How a principal interprets a lesson from *EM* or *Investigations* often differs from how teachers and coaches interpret them. In Capital City, including principals in boundary practices served to expand the coordination of meaning to involve all parties with a say over the interpretation of the *Investigations* curriculum.

Finally, engagement can be fostered not only by creating new communities but also by identifying and building on groups with a shared history. In Capital City, the coaches had a history of shared experiences before the introduction of the *Investigations* curriculum. This shared history of experience became a useful foundation when district leaders introduced the coaching model and recruited many of them to become mathematics coaches.

APPENDIX

IERI – Scaling Up Mathematics
Teacher Protocol-Social Network Questions

(similar questions were asked of coaches and principals)

Introductory script: *One of the things we're interested in learning about is how teachers talk with one another about mathematics instruction and how that makes a difference—or not—in what they do in their classroom.*

Informal social network:

1. Since the beginning of the school year, have you gone to anyone for advice, with a question or concern, or just to talk something through about *mathematics instruction*? If so, who, have you gone to? Who else have you gone to? Anyone else inside or outside of school?
2. For each person mentioned, ask the following set of questions (go through complete set of questions for each person mentioned in turn):
    - [if not mentioned] What role does that person play? [Are they a teacher? What grade? Something else?]
    - How **frequently** have you talked with this person around mathematics?
    - What kinds of things did you talk about?

        Probe:

        - particular teaching challenges;
        - problems with specific students;
        - strategizing about using the curriculum; sharing materials and instructional approaches;
        - creating materials and instructional approaches
        - coordinating instruction with one another
    - What advice, information did they offer? Can you give me an example? [to get at content of conversation]
    - How did you respond to this advice? How, if at all, did this advice/information influence your mathematics teaching? Can you give me an example?
3. Why do you go to some people and not others to talk about mathematics instruction?

    Probe:

    - trust,
    - personal relationship/closeness,
    - attributions of expertise,
    - authority relations (I was required to go to her),
    - anticipation of exchange relationship (I help her so she'll help me)

Interaction in formal settings:

4. What structured opportunities, if any, do teachers have in this school to meet with one another? [probe: whole school meetings, grade level, committees, leadership teams, etc.]
    - When and how often do each of these venues meet?
    - Who do you work with in these settings?
    - What kinds of things do you do in each of these meetings [probe: nature of tasks]?
    - How, if at all, does participation in any of these meetings influence your mathematics instruction?

ENDNOTES

[1] Wenger offers the following indicators of a community of practice: "sustained mutual relationships, harmonious or conflictual; shared ways of engaging in doing things together, rapid flow of information or propagation of innovation; absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process; very quick setup of a problem to be discussed; substantial overlap in participants' descriptions of who belongs; knowing what others know, what they can do, and how they can contribute to an enterprise; mutually defining identities; the ability to assess the appropriateness of actions and products; specific tools, representations, and other artifacts; local lore, shared stories, inside jokes, knowing laughter; jargon and shortcuts to communication as well as the ease of producing new ones" (p. 125).

[2] Capital City School District is a pseudonym. Some Capital City teachers used selected modules of *Investigations* during the 2002-03 school year; summer 2003, however, marked the beginning of comprehensive implementation.

[3] The two New York schools have been given the pseudonyms of Lincoln and Marshall; in the Capital City School District, we've assigned the pseudonyms of Trafford and Bakersfield.

[4] In each district, the instructional superintendent turned over during the first two years of the mathematics reform; in both cases, we interviewed both the initial superintendent and his/her replacement.

[5] A task force was set up to review curricular options for mathematics and asked to send a recommendation to the Deputy Chancellor, the Chancellor, and ultimately, the mayor. Their decision was to implement *Everyday Mathematics* (*EM*) city-wide and to use *Math Steps* as a supplement to provide more practice on basic skills. According to three leaders who were interviewed regarding the selection of *EM*, the choice was a political compromise. Viewed as a boundary object, one might propose that *EM* was selected because each community that was consulted saw something different in it, something that their group endorsed. The union felt that *EM* would be less-stressful and easier to implement for the teachers; HOLD (a local chapter of Mathematically Correct) felt that *EM* had the look of a traditional textbook (the addition of *Math Steps* assured that basic skills would not be neglected); the university-based mathematics educators saw it as a standards-based curriculum that focused on higher-order thinking and reasoning skills. Thus, it is interesting to note, that consensus was reached not because all communities necessarily shared the same goal, but rather, each ascribed a meaning to the selected curriculum that fit with their particular agenda.

[6] There were also regional teacher training events, but they happened infrequently and involved a small subset of the teachers.

[7] The Workshop Model is NYC's instructional approach for both literacy and mathematics. It consists of an opening mini-lesson in which the lesson's main concepts are introduced, a period of student-directed work in groups, and a final "share" period during which students share products from the small group work.

[8] At the same time that *Everyday Mathematics* was selected as New York City's curriculum, *Math Steps* was selected as a supplement to be used primarily for homework assignments.

[9] For example, in the very first RIS meeting (10/03), participants were given 12 student responses to an *EM* problem an asked to group them in a way that made sense. In the subsequent meeting, RISs again examined student work and then viewed a videotape of the lesson within which that work was produced.

[10] The structure of coaching varies somewhat school-by-school. Most schools have teachers coaching individual teachers, including modeling lessons, watching teachers teach and facilitating reflective conversations and action planning. Some schools also have coaches meet with grade level teams once a week. Their role in these grade level teams varies from providing information, leading

discussions on "how things went," to more structured activities like joint planning, common lessons, or looking jointly at student work.

[11] The district expresses the relationship between the curriculum and *Investigations* in the following way: "the purpose of curriculum is to articulate what a child should know and be able to do at each level of their education. The Capital City District Mathematics curriculum was developed by a committee of classroom teachers and specifies what needs to be taught at each grade and to what depth. By having and teaching to a District curriculum, we can be sure that students are receiving instruction in and learning the skills and knowledge necessary to meet State Academic Standards… The district curriculum, materials [*Investigations*], and timeline are aligned with each other. By following the curriculum, and using the materials at the recommended times, students will have opportunities to learn the objectives assessed on the quarterly assessments. You can access the District Mathematics Curriculum on-one through IMS." (district memo, 9/30/2002)

[12] Presently, the district is softening this message and provides suggestions for supplementary materials in places where *Investigations* does not fully address state objectives.

[13] As noted throughout the Capital City case, this was a major focus of all of the boundary practices.

[14] Both curricula are standards-based and teach for conceptual understanding, not simply procedural competence. They do so in different ways, however.

[15] See Stein & Kim (2006) for an analysis of the differences between these two curricula in terms of the learning demands and opportunities that they provide for teachers.

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