Participants in Mathematics Teacher Education

Individuals, Teams, Communities and Networks

Edited by

Konrad Krainer
University of Klagenfurt, Austria

and

Terry Wood
Purdue University, West Lafayette, USA

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ELHAM KAZEMI

9. SCHOOL DEVELOPMENT AS A MEANS OF IMPROVING MATHEMATICS TEACHING AND LEARNING

Towards Multidirectional Analyses of Learning across Contexts

This chapter focuses on supporting the teaching and learning of mathematics through school development. School development entails organizational learning and the use of social, structural and material resources to support teaching and learning: how are schools or mathematics departments organized to support the teaching and learning of mathematics? I begin by reviewing why and how researchers have conceptualized the school as a productive setting for supporting and improving the teaching and learning of mathematics. I draw on literature from organizational learning and professional communities to show how recent studies theorize improving instruction and student learning. Much of the literature emphasizes mechanisms for such improvement to be highly dependent on how schools employ resources and how they are organized to support teachers' collective learning together outside of the classroom. The chapter ends by proposing new directions for research on professional inquiry and its relation to the improvement of teaching and learning mathematics and school development.

INTRODUCTION

In this chapter, I take up the issue of how schools cultivate organizational supports for teaching that aims to successfully engage all kinds of learners in complex mathematical learning. In particular, I hold a view of mathematical learning that respects students' intellectual integrity and considers schools to be places for vibrant intellectual engagement in which students and teachers develop sophisticated understanding of mathematics, identities as mathematical thinkers, and are engaged in ongoing inquiry. My interest in school development is to understand what allows the school community to continually strive to improve mathematics instruction in order to strengthen student learning. Much of the literature on school development naturally focuses on supporting teacher learning and building teacher capacity (see e.g., Borko, Wolf, Simone, & Uchiyama, 2003), 2003; Lerman & Zehetmeier, this volume; Nickerson, this volume). Thus, a large portion of this chapter is devoted to research focused on cultivating professional communities where teachers are the major players. In considering school development, I view membership in a school's professional community to include teachers, instructional leaders (e.g., coaches), and administrative leaders. A school

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development perspective emphasizes the interdependence of professionals in the school community – how schools carve out time and space and employ social, intellectual, and material resources to support joint inquiry among teachers, instructional leaders and administrators (Collinson, in press; Lampert, Boerst, & Graziani, under review). I review how researchers have conceptualized and described this joint inquiry and propose directions for future research.

DEVELOPING A SCHOOL'S ABILITY TO SUPPORT MATHEMATICAL LEARNING

What Is Organizational Learning?

One of the strengths of the mathematics education literature has been our careful attention to supporting teachers to improve their instruction. My goal in this chapter is to harness our understandings of supporting individual teachers to think about school-wide professional learning (see also Knapp, 1997; Krainer, 2006; Oliveira & Hannula, this volume; Perrin-Glorian, DeBlois, & Robert, this volume). One clear area of growth for mathematics education research on school development is to develop a framework for explaining how activities engaged by teachers and other professionals at the school level achieve organizational purposes and affect student learning outcomes (Boreham & Morgan, 2004). Collinson and Cook (2007) define *organizational learning* as "the deliberate use of individual, group, and system learning to embed new thinking and practices that continuously renew and transform the organization in ways that support shared aims" (p. 8). According to Boreham and Morgan (2004), when organizations learn, "co-workers transcend the boundaries which separate them from colleagues, establish a common (and expanded) understanding of the object of their joint activity and make a collective decision on how to achieve it" (p. 313). In recent work, Lampert et al. (under review, p. 35) have been examining how organizational assets – material, intellectual, and social – become resources to support successful teaching of complex learning; they explain this view in the following way:

> Assets are effective in supporting the common practice of ambitious instruction when they are widely used as tools for solving common instructional problems. When common use is enabled by the organization of practice, assets can shape the culture of teaching and learning. For this reason, our analysis has focused not only on the nature of material, social, and intellectual assets, but also on how instruction at the school is organized so that assets can become resources that are routinely drawn upon to support a challenging approach to teaching and learning across the school.

Lampert et al.'s views echo other researchers who suggest that we need to move beyond making direct causal links between resources available at a school level (such as adequate funding, leadership, highly qualified teachers, curricular materials, release time for teachers) to student achievement. Instead, the argument is to examine how such resources are used to support instruction, which mediates student achievement (see also Cohen, Raudenbush, & Ball, 2003).

Professional Inquiry as a Key Resource in Supporting School Development

The existence of robust professional inquiry at the school level has received a considerable amount of attention as one of the key resources in supporting school development. Promoting collective professional inquiry within a school emerged in part as a response to a large body of organizational and classroom research that documented the successes and failures of teachers' attempts at implementing reform practices designed to change classroom instruction. Changing daily routines inside classrooms, the goals and purposes of mathematics instruction, and dominant discourse patterns and relationships between teachers and students have proven difficult. Significantly impacting classroom instruction is challenging because of what organizational researchers have labelled the *loose coupling* between traditional school structures, management, and teachers' everyday decision-making. While teachers may enjoy considerable autonomy, this loose coupling in traditional organizational structures creates barriers for instructional reform (Weick, 1976). More recent work on teachers' responses to reform initiatives suggests that the congruence, intensity, pervasiveness and voluntariness of the reforms themselves have an effect on how teachers change their classroom practices (Coburn, 2004). Decoupling may be one of many responses teachers have to reform initiatives. Others include rejecting reform visions, assimilating, accommodating, or developing parallel structures to reform practices.

To counter forces that keep teachers isolated and encourage idiosyncratic responses to instructional initiatives, researchers have attempted to build models that are built into the regular workday, arguing they have more promise of being maintained, sustained and integrated into teachers' practice than an occasional weekend or summer institute (see also Jaworski, this volume; Lerman & Zehetmeier, this volume). A focus on schools as a unit of change means that a collective intellectual culture needs to be cultivated among key professionals (administrators, instructional leaders, and teachers) who work within the organization. Basing professional inquiry within the workplace can allow school professionals to work together to make sense of demanding mathematics teaching and coordinate their efforts across grade levels. Importantly, collective inquiry serves to break down the dominant "*egg crate model*" of schooling – teachers housed together in a school yet working individually in their own classrooms with little coordination and collaboration with colleagues in the same building. The dominant cellular model has promoted isolation and norms of privacy (Lortie, 1975). That said, it is important to note, as many researchers have pointed out, that simply bringing teachers and leaders together in regular meetings does not mean they will be able to critique and learn from their practice. How learning opportunities are structured and enacted make all the difference in teacher learning.

To the extent that we have conducted cross-national comparisons of teaching, we know that variation does exist in what counts as "doing" school mathematics. The case could be made that a view of mathematics as a static body of procedures to memorize and apply with fidelity is a vision that many mathematics educators in the US try to move away from in their professional development work with

teachers. Much of the literature about supporting instructional improvement is aimed toward helping teachers learn to treat mathematics as a sense-making enterprise that involves argumentation, reasoning, and justification at its core (see also Seago, this volume). Cross-national comparisons have helped us see that expository teaching approaches are not necessarily universal. In elementary classrooms in Japan, for example, significant time is spent on justifying and connecting mathematical ideas (Hiebert, Stigler, Jacobs, Givvin, & Garnier, 2005). It may be fair to say that a procedural approach to teaching and learning mathematics is nonetheless ubiquitous (Givvin, Hiebert, Jacobs, Hollingsworth, & Gallimore, 2005). Although some variation exists internationally in cultural scripts for teaching (Clarke, Emanuelsson, Jablonka, & Mok, 2006; Clarke, Keitel, & Shimizu, 2006), static notions of learners, especially durable notions of ability and competence may be more pervasive across the globe. Schooling institutions are typically organized to classify, sort, and promote students with higher mathematical ability and higher achievement (e.g., Spade, Columba, & Vanfossen, 1997). Schooling practices can embody a view of ability that often takes intelligence as an inherent and stable trait (Boaler, 2002; Horn, 2007). Reforming mathematics instruction at a school level is often coupled with trying to upend static views of students' ability and intelligence in order to subvert tracking, grouping, and classification systems that keep students in ability bins (e.g., Boaler, 2002, Horn, 2007; Oakes, 1985; Rousseau, 2004; Sfard & Prusak, 2005). This view sees schools and classrooms as "necessarily cultural and social spaces that can perpetuate social inequities by positioning multiple forms of learning and knowing as 'having clout'" (DIME, 2007, p. 407). Promoting school development has the potential to enable school professionals to interrogate how they view students in relation to instruction and how their actions and policies privilege certain students over others.

Visions of Ambitious Teaching, Teacher Learning and the Meaning of Inquiry

Current research on teaching and learning puts forth a vision of teaching mathematics that has been labelled a number of different ways: teaching for understanding, reform-oriented teaching, standards-based instruction, problem-centred instruction, inquiry-oriented teaching. These terms have been used to convey both a level of intellectual rigor, and the nature of the classroom community needed to achieve that rigor. Lampert and colleagues (under review) use the term *ambitious teaching* to mean, "adjusting teaching to what particular students are able to do (or not)" (p. 2) in order to engage all kinds of students in complex problem solving activity, mathematical reasoning, and justification; they identify the challenges of ambitious teaching to include (p. 35):

- Teachers need to move around flexibly in the multiple dimensions of subject matter in relation to student performance, adjusting teaching to learning.
- Teachers need to create an environment where students are willing and motivated to take the risks that intellectual performance entails.

– Teachers need to take what students can do as an integrated indication of what they know and what they need to learn rather than breaking subject matter into meaningless bits of information.

To meet such challenges, it seems reasonable to argue that teachers must have access to substantive learning opportunities for themselves. The literature on teacher learning is replete with uses of the term inquiry. Richardson (1994) distinguishes formal educational research from teachers' own *practical inquiry* by describing how practical inquiry aims to help teachers change their instructional practice or increase understanding by studying their own contexts, practices, or students. When conducted with colleagues, practical inquiry can develop a local sense of shared norms and local standards of practice. Cochran-Smith and Lytle (1999, p. 288) describe inquiry as *stance:*

> Teachers and student teachers who take an inquiry stance work within inquiry communities generate local knowledge, envision and theorize their practice, and interpret and interrogate the theory and research of others. Fundamental to this notion is the idea that the work of inquiry communities is both social and political; that is, it involves making problematic the current arrangements of schooling; the ways knowledge is constructed, evaluated, and used; and teachers' individual and collective roles in bringing about change.

The critical perspective reflective in Cochran-Smith and Lytle's view of inquiry as stance is reflected in other views of professional inquiry designed to help teachers not only develop new knowledge and skills but interrogate their views and question and critique the political nature of schooling as it relates to students learning mathematics (e.g., Gutiérrez, 2007; Horn, 2005; King, 2002). This more critical stance of inquiry is an attempt to support teachers to consider how schools and learning opportunities affect access and equity in students' academic identities and trajectories in successfully learning mathematics and pursuing mathematics as they continue through schools.

Viewing schools as *sites for teacher learning* rather than as places where teachers simply work is well supported by sociocultural theories of learning. Drawing from the notion that knowledge and meaning are constructed through practice, Franke, Carpenter, Fennema, Ansell, and Behrend (1998, p. 68) argue for supporting learning that is self-sustaining and generative; they claim that teachers' supported efforts to engage in classroom practices guided by student learning can serve as a basis for their own continued growth and problem solving of classroom dilemmas:

> It is in developing an understanding of their practices in relation to their students' learning that teachers develop the understanding necessary to generate new ideas. If a teacher struggles to understand why the students are successful, how they are solving problems, how their thinking develops, and how instruction might help students to build on their current conceptions, connections are made, understanding develops, and the potential for more

connections becomes possible. Thus, there exists a basis for the teacher to learn and continue to grow.

Through Franke and colleagues' work, we have learned how teachers can use their own practices to make sense of student learning. However, we need to understand further how teachers' classroom practices and broader school-based professional communities can provide the basis for teachers to continue to develop their practice. In their work, Franke and colleagues argued that teachers who are generative develop detailed understanding of their own students' thinking, organize that knowledge and view it as their own to create, adapt, and change. These teachers learn from interacting with their students; they are focused in the ways they listen to, interpret, and make use of their students' thinking. In this chapter on school development, I consider how teachers' participation in multiple and potentially overlapping communities of practice shapes and re-shapes their identities and constitutive skills and knowledge as teachers of mathematics.

THEORIZING ABOUT PROFESSIONAL COMMUNITY

The main mechanism for supporting teachers' generative learning for ambitious teaching has been through building and sustaining *professional communities* of teachers. Theorizing teacher learning through participation in professional community draws on sociocultural theories of learning which take participation as a key construct (see also Jaworski, this volume). Lave and Wenger (1991) define a *community of practice* as "a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping communities of practice" (p. 98). A community of practice can be defined through *mutual engagement* in a *joint enterprise* which develops *shared repertoire*s of practice (Wenger, 1998). Lave (1996) describes learning as "changing participation in changing 'communities of practice'" (p. 150). Learning is not a process of acquiring or transmitting knowledge. Rather learning is apparent in the way participation transforms within a community of practice (Rogoff, 1997). The shifts in participation do not merely mark a change in a participant's activity or behaviour; a shift in participation also involves a transformation of roles and the crafting of a new *identity*, one that is linked to but not completely determined by new knowledge and skills (Lave, 1996; Lave & Wenger, 1991; Rogoff, 1994, 1997; Wenger, 1998). Lave (1996, p. 157) states, "crafting identities is a social process, and becoming more knowledgeably skilled is an aspect of participation in a social practice. By this reasoning, who you are becoming shapes crucially and fundamentally what you 'know'." Knowledge and the development of skill are clearly important in understanding learning. Developing skill and knowledge is in service of changing participation in a particular community.

Lave and Wenger (1991) describe *transforming participation* in terms of movement from legitimate peripheral to full participation. As a legitimate participant, one is connected and belongs to the community of practice in question, but as a peripheral participant, one engages less fully in the community. The

peripheral participant has access and can move towards full participation, thus developing an identity of full participation. Full participation entails "developing an identity as a member of a community and becoming knowledgeably skillful" (Lave, 1991, p. 65). Analysis of learning focuses on the structuring of the community's work practices and learning resources; learning is detectable in members' participation in the work of the community.

What Does Professional Community Mean for Mathematics Teaching and Learning?

As mathematics education researchers have drawn on the community of practice theory, they have identified key features of professional community, the strength of which inspires instructional innovation and commitment to students. Several reviews exist which compare these features and common to all these communities is a shared sense of purpose and collective and coordinated collaborative activity with a commitment to students (e.g., Dean & McClain, 2006; Sowder, 2007). Dean and McClain (2006, pp. 13–14) define these as:

> *A shared purpose or enterprise* such as: ensuring that students come to understand central mathematical ideas while simultaneously performing more than adequately on high stakes assessments of mathematics achievement.
>
> *A shared repertoire of ways of reasoning with tools and artefacts* that is specific to the community and the shared purpose including normative ways of reasoning with instructional materials and other resources when planning for instruction or using tasks and other resources to make students' mathematical reasoning visible.
>
> *Norms of mutual engagement* encompassing both general norms of participation as well as norms specific to mathematics teaching such as the standards to which the members of the community hold each other accountable when they justify pedagogical decisions and judgments.

Gutiérrez (1996) calls high school mathematics departments with strong professional communities as "*organized for advancement*" because their collective activity makes a difference in advancing student learning and achievement. In addition, several researchers emphasize teachers' ability to wield influence and control over important decisions that affect a school's activities, policies, and curriculum (Erickson, Brandes, Mitchell, & Mitchell, 2005; King, 2002; Little, 1999; Secada & Adajian, 1997).

Cultivating Professional Inquiry at the School Level

This chapter underscores the idea that school development necessarily involves learning. Boreham and Morgan (2004) argue that organizations learn because members of the community are able to coordinate their perspectives and actions

towards achievement of common goals. They found that organizations learn by developing *relational practices,* "the kind of practice[s] by which people connect with other people in their world, and which direct them to interact in particular ways" (p. 315). These relational practices include:

– opening space for creation of shared meaning
– reconstituting power relations
– providing cultural tools to mediate learning.

Those relational practices can be connected to developing social and intellectual resources (opening space for creation of shared meaning and reconstituting power relations) and material resources (providing cultural tools to mediate learning). In what follows, I draw on the professional community and inquiry literature to identify the following dimensions that make possible these relational practices.

– Activating school leaders
– Navigating fault lines, dealing with micropolitical issues among teachers
– Developing and sustaining a focus
– Engaging parents as intellectual and social resources

Activating school leaders. When the school is the centre of change, theories of action for supporting professional learning communities (PLCs) among mathematics teachers necessitate contention with school cultures and institutional realities. Gamoran and colleagues (2003) contend that PLCs need access to resources – material, human, and social – if they are to remain viable. Here the role of school leaders in facilitating the availability and use of such resources can be critical. School leaders refer not only to school principals or heads but also to curriculum leaders, mathematics coaches, teacher mentors, or faculty coordinators. There is variance documented in the literature as to how much direct involvement in a professional community principals have versus other mathematics leaders (Burch & Spillane, 2003; King, 2002; Krainer & Peter-Koop, 2003; Wolf, Borko, Elliott, & McIver, 2000). In some cases, principals participate in teacher meetings in order to learn alongside teachers and spend time in classrooms. In others, the principal is supportive by allocating school level resources in providing space and time and by making goals of teacher interactions congruent with school and district level goals (Coburn & Russell, in press). Whether and how leadership strategies interact with supporting professional development in a PLC at the school level in mathematics, is a burgeoning area of research. Findings underscore the situated way in which leadership strategies interact with local conditions.

Halverson (2007) documented the way school leaders make use of certain structures to enable the building of a professional community. Key to Halverson's (2007) analysis is that a professional community is a "form of organizational trust" (p. 94) resulting from the kinds of interactions teachers have to consider in using alternative instructional strategies to improve student learning. His analysis of the role of school leaders in supporting a professional community focuses in part on *leaders' use of artefacts*, such as role positions, daily schedules, meetings and meeting agendas. Moreover, he found that school leaders sequence the use of these

artefacts in different ways to initiate interactions, facilitate development of mutual obligations, and provide feedback about how those obligations are being met at a systemic level. One of the key material resources in supporting teachers' ability to work together is *time and space* and to do so in the rushed pace of the normal work week. Halverson found that leaders strategically made use of local contingencies in order to carve out space and time for teachers to initiate and legitimate time to talk about instruction – in one case through Breakfast Club meetings and in two others through grant-writing projects to respond to a new accountability mandate. Examples abound in the literature of other means that school leaders employ to initiate conversations, including such things as analysis of student work (e.g., Kazemi & Franke, 2004), implementing common units of lessons (e.g., Borasi, Fonzi, Smith, & Rose, 1999), study groups (e.g., Arbaugh, 2003), and regular department meetings (e.g., Horn, 2005). Coburn and Russell's (in press) use of *social network analysis* also supports the importance of school leaders in allocating human resources such as coaching expertise in collective professional interaction. They found that the allocation of coaches affected depth of interactions in PLCs.

Navigating fault lines. Establishing professional communities is not just a matter of decreeing that one exists. There is nothing neither positive nor harmonious inherent in the term community, and if we consider the countless times researchers have characterized the work of teaching and school reform as complex, we should expect that forming inquiry communities within schools should not be a trivial matter. Research on PLC and school-based reform has highlighted how managing tensions and conflicts are critical for the viability of the PLC (Rousseau, 2004). Grossman, Wineburg, and Woolworth (2001) identified the navigation of *fault lines* as one of the central concerns of building a supportive teacher community. These fault lines are not necessarily interpersonal conflicts among teachers but may be tensions regarding disciplinary goals and views of teaching and learning mathematics that exist in the school or department (e.g., Rousseau, 2004). Because participating in a PLC is about *changing school cultures* and *breaking norms of privacy* while at the same time *building norms of critical colleagueship*, researchers have also attended to the ways such participation affects transformations in *teacher identity* (e.g., Drake, 2006; Kelchtermans, 2005; Battey & Franke, in press). Researchers argue that teachers' individual reactions to a PLC's demands are mediated by social and cultural contexts as well as teachers' working dynamic identities. "Teachers' identities carry personal histories, emotion, values, and knowledge and they shape how teachers participate in professional development and their classrooms" (Battey & Franke, in press, p. 27).

Research has discussed the paradoxes and conflicts that are bound up in cultivating PLCs. Many researchers have noted that in order for teacher inquiry to have a school-wide effect, it must move beyond individual teachers. But mandating participation in teacher inquiry at the school-level can also backfire. Here leadership must be strategic in inviting a critical mass of participation that can have a pronounced affect on school culture (Berger, Boles, & Troen, 2005; Krainer,

2001). The role of key school leaders (whether principals, school facilitators, or coaches), again becomes critical in creating a press for teacher inquiry *and* in developing collective ownership (Berger et al., 2005; Nickerson & Moriarty, 2005).

Developing and sustaining a focus. If schools are successful in carving out time and space for teachers to meet together, in managing conflicts and tensions, the next dimension I wish to highlight is how researchers describe the importance of developing and sustaining a focus on students. Because time and space are precious resources in schools, collegial interactions need to be focused in order to be productive. Some studies indicate that material resources such as curriculum units or lessons, student work, videotaped lessons can be leveraged successfully in order to achieve this focus (e.g., Borasi et al., 1999; Kazemi & Franke, 2004; Seago, this volume; Sherin, 2004). Lin's (2002) study is illustrative. The school-based professional inquiry she described focused on grade-level collaborations. First-grade teachers met to develop, observe, and reflect on lessons from the Taiwanese mandated learner-oriented reform curriculum. To provide sufficient focus for their collective inquiry, the first-grade teachers selected a common lesson to plan and observe in each other's classrooms. They used these common lessons and observations to write classroom cases that in effect focused and deepened their conversations, beyond what observation alone would have accomplished. Three types of cases emerged from this collaborative inquiry: (1) analysis of students' varied solutions and strategies; (2) students' interpretations of other students' thinking; and (3) comparisons of two different instructional approaches to teaching the same topic. Cases were developed in several phases; each successive phase refined and elaborated the teaching context and the questions for discussions. The creation of teaching cases situated in teachers' own classrooms when all teachers were able to teach the same lesson enabled the teachers to very carefully analyse the effect of task design and sequencing on students' mathematical thinking; students' ability to use symbolic and pictorial representations to solve problems; and for teachers to compare and think deeply about how their instructional choices (e.g., "Is binding straws important for students' ability to count by tens?") impacted student performance. This was dependent, of course, on teachers' willingness to examine their own practice and to raise questions for one another. This kind of inquiry is dependent on cultivating norms of inquiry, navigating fault lines, and developing resources for time to meet.

Engaging parents as intellectual and social resources. The *role of parents* in school development has received much less attention than the work of teachers, administrators, and leaders. This makes sense given the amount of attention of coordinating professionals who work at the school itself. Nonetheless, recent work on parents has illuminated a number of issues related to parents' engagement, raising possible considerations for parents' role in supporting school development.

Improving mathematics instruction involves a dramatic transformation from viewing mathematics as a fixed body of procedures to memorize and apply with

fidelity to a discipline that is fundamentally about complex problem solving, justification, and argumentation. Studies investigating parents' views have revealed that parents can feel disempowered in relation to reform-oriented mathematics (Martin, 2006; Remillard & Jackson, 2006). At the same time, interventions that have aimed to work with families around mathematics as a complex problem solving discipline have reported significant increases in families' feelings of empowerment (Civil & Bernier, 2006). Reports of building school capacity may include events such as *parent nights* designed to mitigate these anxieties by beginning dialogue with families about goals of ambitious mathematics teaching and learning (e.g., Kramer & Keller, 2008). We have much more to learn about how engagement with families can support school development efforts, in what kinds of social and political contexts, and to what ends. Might leadership, for example, leverage family views, practices and questions to catapult teacher inquiry (e.g., Anderson, 2006) or could family practices undercut professional community?

Studying the Practices of School-Based Professional Communities

Cultivating a viable professional community naturally begs questions about how members of the school community actually interact with one another as they discuss teaching practice. What might it look like for teachers and leaders to engage in *critical colleagueship* (Lord, 1994) oriented to improving mathematics teaching and learning? I find the work of Little and Horn (2007) to be particularly instructive in thinking about the practices of a professional community. They are developing a conceptual scheme to examine what actually happens in collective professional learning communities. How do participants actually work together? What do they say and do? How do they interact with one another around artefacts of practice and how do they talk about classroom instruction? Little (2002) offers two central questions for examining interactions within teacher communities:

1. What faces of practice are made visible through talk and with what degree of transparency?
2. How does interaction open up or close down opportunities to learn?

The *face* of practice refers to "those parts of practice that come to be described, demonstrated, or otherwise rendered in public exchanges among teachers" (Little, 2002, p. 934), which may include artefacts such as student work. *Transparency* of practice conveys "how fully, completely, and specifically various parts of practice are made visible or transparent in the interaction" (Little, 2002, p. 934). These two questions seem central to us in order to understand what views of practice are made available to teachers through their collective inquiry. As I describe below, I contend that the understanding of the inner workings of school-based professional development communities should be then related to teachers' participation in and out of the group setting. This relational view can help us understand who teachers are becoming through this process (Battey & Franke, in press; Enyedy, Goldberg,

& Welsh, 2006), and how they are enacting their developing identities, skills, and knowledge with their students in the classroom.

Little and Horn (2007; see also Horn, 2005) have documented in detail how the rendering of classroom interactions in professional conversations shape opportunities for teacher learning. By contrasting informal conversations in mathematics department meetings in two different high schools, they compare how teachers use *replays* and *rehearsals* to reason publicly about their instructional practice and to consider alternative interpretations and re-formulations of pedagogical dilemmas and problems in ways that propel their teaching forward. During replays, teachers recount "blow-by-blow accounts of classroom events, often acting out both the teacher and students' roles" (Horn, 2005, p. 225). Through rehearsals, teachers act out classroom interactions that might occur in the future, anticipating what they might say and how students might respond. In careful analysis of teacher-to-teacher talk, Horn documents how teachers move in and out of these modes as they reconsider their pedagogical choices and ready themselves for continued experimentation. However, the presence of replays and rehearsals during collegial interactions is not sufficient for such experimentation. How such replays and rehearsals function in framing pedagogical issues, questions, dilemmas and frustrations is what matters.

Prior work by Kazemi and Franke (2004; see also Franke & Kazemi, 2001; Franke, Kazemi, Shih, Biagetti, & Battey, 2005) documented detailed images of the evolution of collective inquiry among elementary teachers analysing their students' mathematical work in monthly school-based meetings in which each teacher had posed a similar mathematical problem (focused on number and operations) to his or her class. The analysis of the teacher talk revealed that the workgroup conversations evolved as teachers learned to talk about their work. Salient developments included the following:

- Teachers first had to learn to *attend to the details of their students' thinking*. Even though meetings were structured from the very beginning to detail students' strategies, teachers did not come to the first meeting prepared to do so. Instead, many teachers assumed that the pieces of paper themselves would tell the story. It was further evident in the way they posed the problems that many assumed that conversations with students about their solutions were not necessary. Maintaining the structure of the workgroup promoted an emphasis on documenting the details of student thinking. Kazemi and Franke (2004) intentionally facilitated the discussions so that teachers would return to the idea of noticing how students were learning to break apart and put together numbers using their knowledge of the base ten structure of the number system. In order for teachers to interpret their students' reasoning, they began to use the student work as a trace rather than a complete record of their students' reasoning. Without such a mathematical focus, meetings may not encourage teachers to follow a particular course of experimentation in their classrooms.
- Teachers' close consideration of student reasoning opened up *opportunities to deliberate mathematical and pedagogical questions*. Examining student work, as structured in this professional development, allowed teachers to surface their

confusions and uncertainties, not just about student reasoning but also about mathematics and classroom practice. The discussions opened up opportunities for teachers to notice the mathematical ideas students were using. This led to the group's engagement with sophisticated computational strategies they were noticing in their classrooms. The use of student work provided an entry point for teachers to explore mathematical ideas and have opportunities to make sense of efficient student-generated algorithms. Pedagogical issues related to helping children develop more sophisticated strategies also surfaced once the group saw students in teachers' own classrooms using such strategies.

– *Diversity in teachers' experimentation served as a resource for learning*. Teachers differed in how they reported on their engagement with students in their classrooms. Not all the teachers experimented with these ideas in the same way. Because the group had multiple ways of relating the professional development discussions to their classroom practices, the experiences of some teachers generated new conjectures about what to try in the classroom. The frustrations teachers shared in the group also underscored the challenges they faced in helping children articulate and build their ideas. This diversity became a resource for teachers to compare and question each other's practices.

Understanding how teachers' interact with one another in PLCs and how those interactions evolve and develop learning opportunities for teachers is vital for research and development work in fostering collective inquiry at the school level. In the next subchapter, I argue for relating this evolving research base to the well-known research on teachers' classroom instruction.

CONNECTING PROFESSIONAL LEARNING COMMUNITIES WITH CLASSROOM TEACHING AND LEARNING

Earlier in this chapter, I proposed the view that school development deals with the development of organizational supports for ambitious mathematics teaching and learning. Much of the literature emphasizes mechanisms for such improvement to be highly dependent on how schools employ resources and how they are organized to support teachers' collective learning together outside of the classroom. What I would like to offer in the remainder of this chapter is a proposal for attending to one aspect of the relationship between *joint inquiry* at the school level and classroom instruction. My discussion is not meant to be comprehensive; it identifies one shortcoming of how we have typically thought about the impact of teachers' and leaders' joint inquiry on mathematics instruction and student learning. Some of our current research base is limited in scope to a unidirectional view of the impact of cultivating professional inquiry at the school level to teachers' classroom practice. I propose that what needs to be addressed and developed are ways to characterize and document the *multi-directional influence between participation in joint inquiry and the individuality of classroom practice*. In this last subchapter, I outline the rationale for this approach and describe some of the necessary theoretical and empirical work that lies ahead.

Teachers are simultaneously involved in multiple activity settings, including their own classroom, school, and district. When they are involved in sustained inquiry with colleagues and leaders at the school, this constitutes another important mediating context. I use the construct of *activity settings* to focus on the boundaries and relationships between the classroom, school and district (see also Cobb & Smith, this volume). Activity settings overlap; that is, they do not exist as insular social contexts but rather as sets of relationships that coexist with others (Engeström, 2001). Activity settings can have temporal, conceptual, and physical boundaries (Grossman, Smagorinsky, & Valencia, 1999). It is this *dynamism across activity settings* and how that shapes teacher learning that I am concerned with in this chapter. To develop these ideas further and specify a way of talking about learning, I draw on Cook and Brown's (1999) distinction between *knowledge* and *knowing*. Knowledge, in their view, is something that we "possess". We "deploy" this knowledge in our actions. In their words, "Knowing refers to the epistemic work that is done as part of action or practice, like that done in actual riding of a bicycle or the actual making of a medical diagnosis" (p. 387). Knowledge, then, can be seen a tool of action because individuals or groups can use knowledge (whether tacit or explicit) to discipline their interactions with the world. This distinction seems both relevant and important in thinking about teacher learning. Much has been written about the kinds of specialized knowledge that teachers need, among them, knowledge of the discipline, their students, and instructional strategies (Ball & Bass, 2000; Shulman, 1986). Professional inquiry clearly needs to develop teachers' knowledge, and we have been rightfully concerned with figuring out what kinds of knowledge teachers gain through inquiry.

Cook and Brown (1999) would agree that knowledge is essential for practice but it is not sufficient for explaining what it takes to be good at what you do: "An accomplished engineer may possess a great deal of sophisticated knowledge; but there are plenty of people who possess such knowledge yet do not excel as engineers" (p. 387). In addition to all the kinds of knowledge that teachers need, they also have *to be able to teach*. For me, this means that we have to attend to the *interplay between knowledge and knowing* in the professional community and in teachers' classroom context. In addition, we need to attend to the interplay between teachers' development of knowledge and ways of knowing in the professional development and classroom contexts over time. We need to link the knowledge and ways of knowing that teachers develop together with what happens as teachers try to use the knowledge and ways of knowing they gain in joint inquiry in the context of their classroom teaching. Teachers may develop similar ways of examining and talking about students' mathematical thinking through inquiry with colleagues in their school but we clearly need to concern ourselves with how they are drawing on that knowledge when they interact with students, or in Cook and Brown's terms, how knowledge is deployed in the service of disciplining action (knowing). Moreover, I argue that researchers should examine what teachers are learning during and after conversations with colleagues, looking at the *coevolution* of participation between classroom practice and professional inquiry. I claim that this

coevolution between the contexts of professional collaboration and classrooms should itself be a key unit of analysis as we try to explicate the mechanisms by which teachers learn in and through professional inquiry. By seeing how teachers' participation across these contexts co-evolves, we will have better views of the relationship between joint professional inquiry, learning and instruction, and school development.

The Implications of a Multidirectional Analysis for Studying and Designing Collective Inquiry

A multidirectional analysis of professional learning across contexts where teachers and leaders work together and the classroom leads us to the following implications for the study and design of these efforts. We should: (1) understand and elicit the diversity of teachers' experimentation and the effect of depictions of that work in joint inquiry and (2) examine the situated nature of primary artefacts.

Understanding the diversity of teachers' experimentation. In order to understand the relationship between the contexts of joint inquiry and the classroom, and how teachers' and leaders' participation across these settings co-evolves, we must understand individual teachers' classroom experimentation, and how this influences their collaboration with colleagues. How do teachers deploy their knowledge in the classroom? What ways of knowing do they demonstrate in their instructional practice? What do teachers bring to the collective as a result of their experimentation? In addition to documenting the diversity of individual teachers' classroom experimentation, we also need to document and study what actually happens when teachers and leaders come together and their collective learning trajectories as they participate in this context. It is essential that we document the diversity of teachers' classroom experimentation and study the nature of how this experimentation relates to their experiences over time with their colleagues and to their developing identities – what kinds of teachers do they want to become? What ways of knowing are developed over time? How and what knowledge do teachers develop of subject matter, students' thinking, and practice as they engage in collective analysis around common objects of inquiry?

While the argument here is about research on teachers' joint learning, there are also implications for the design of *collective inquiry* (see also Jaworski, this volume; Seago, this volume). I argue not only that teachers' experimentation should be studied but that leaders of teachers' joint inquiry should incorporate *depictions* of teachers' classroom experimentation in collaborative engagement. Depictions of practice are images or stories that seek to capture the events in the classroom as they played out, earlier referenced as replays and rehearsals. They are created intentionally to support the analysis of teaching. Written cases and video-cases are perhaps the most visible example of depictions available in the literature. But there are other examples: replays and rehearsals (Horn, 2005) are depictions

that are created through teachers' talk; teachers' journals can also serve as a depiction.

If professional educators sought openings to elicit teachers' experimentation in a principled way, collective inquiry could serve as a place to pursue questions and dilemmas teachers encounter as they engage in transforming their practice. While it is easy to advocate that we incorporate depictions of practice and discuss teachers' classroom experimentation in the context of collective inquiry more extensively, I recognize that sharing episodes from the classroom can easily and unproductively spiral into a show-and-tell. Leaders of collective inquiry will need to become more knowledgeable and skilled about how to use teachers' classroom experiences. For example, how can the dilemmas teachers face about modifying tasks, managing pacing, and orchestrating classroom discourse be usefully depicted and used as a springboard for discussion? How can leaders utilize one teacher's experiences to support another to develop more focused and reflective attempts to experiment in the classroom? Many researchers have written extensively about the intentional use of records of practice (e.g., Sherin, 2004; Lampert & Ball, 1998; Little, 2004), arguing that we must attend not only to the careful selection of representations but also how they are negotiated in practice.

Examining the situated nature of primary artefacts. *Primary artefacts* are objects that originate (or are produced for use) in instructional practice. In the case of teaching, primary artefacts include copies of student work, lesson plans, mathematical tasks, and curriculum materials. They can travel across boundaries, into contexts where teachers and leaders collaborate, but they are not created solely for the purpose of collectively analysing teaching. Primary artefacts allow particular components of teaching to be extracted from the context of instructional practice, lessening the complexity by narrowing teachers' focus.

Primary artefacts are produced and used in practice, and so ways of knowing include the use and production of primary artefacts. If we are concerned with teachers developing new ways of knowing in their classroom practice, then we should attend to the relationship between ways of knowing in professional development and in the classroom. And if we are going to use primary artefacts as a tool in professional development, we must attend to how they are situated in particular activities, and how this affects their meaning. For example, student work is a primary artefact commonly used in collective work of teachers. The way student work is situated in collective inquiry may look very different from its use in the classroom. Teachers and leaders may sit together to analyse a collection of pre-selected student work to illustrate the range of solution strategies students used in their classroom. They may spend extended time debating what students understand, generating questions they might ask to better understand the students' thinking, or considering which strategies they would choose to highlight in a whole class discussion. In contrast, in their classrooms, teachers may only have a few minutes to survey students' written work in order to make assessments and instructional decisions. The teacher typically engages in this work alone, in the midst of a lesson, while students are working on the task. While collective inquiry

may certainly help teachers gain knowledge they can deploy in this classroom situation, it may not help them develop the ways of knowing they need to monitor students in the moment and to interact with them in ways that assess and advance students' mathematical thinking. Researchers and leaders must attend to the meaning teacher's make of primary artefacts across contexts as these artefacts are situated in different activities. We need to better understand how the ways of knowing involved in these activities differ, and how they influence one another.

CONCLUSION

Writing about school development is necessarily a synthetic enterprise. In this chapter, I conceptualized school development as a school's efforts to support ambitious teaching and learning. Specifically, I took a learning perspective on school development. This perspective highlights how schools support professional learning. Collinson (in press, p. 7) states:

> Vibrant, innovative organizations work at developing their organizational capacity by establishing an environment in which members, and thereby the organization, can continuously learn and improve. Developing members, along with careful recruiting and hiring of fresh talent, ensures innovation and renewal.

The way we understand and study professional learning in schools has significant implications for the way we structure and support teachers' collective learning opportunities, the goals we create for inquiry, and as researchers and educators, the ways we collaborate with schools to improve mathematics teaching and learning. To understand teacher collective learning within the context of school-based professional development, I have argued that we need to develop conceptual frameworks to take into account both the dynamics of individual teacher learning and vulnerabilities to developing their instructional practices as well as the resources and settings that support learning.

One noteworthy aspect of writing this chapter on school development was the opportunity to review research that draws on both classroom level research and organizational and policy implementation research. New collaborations forged between classroom researchers and policy or organizational researchers (e.g., Cobb & Smith, 2007; Cobb & Smith, this volume; Gamoran et al., 2003; Little & Horn, 2007) can enrich our view of designing for a tighter coupling between teacher learning and whole school development that would ultimately benefit professional culture within the school and students' mathematical learning. That said – here are a number of issues that remain to be incorporated into our studies of and designs for school development.

– We need to explicate significant differences between working with schools at the primary and secondary level and how those impact the ways schools support ambitious teaching and learning. There seem to be different challenges with respect to teachers' skills and identities as mathematics teachers, tracking or grouping practices, testing practices and their consequences, curriculum

organization, and relationships among teachers, school leaders, and parents (e.g., Lee, Smith, & Croninger, 1997; Spade, Columba, & Vanfossen, 1997).
– As was evident in this chapter, the research literature on school development attends predominantly to the role of teachers and school leaders. How parents and families figure into school development and supporting ambitious teaching remains underdeveloped and undertheorized.
– Our understanding of school development can be strengthened through further study of how prospective and novice teachers are involved in collective inquiry as a way to recruit and continue to develop practices of the school community (see Leikin, this volume).

Our field's ability to address these issues and others over the next decade will advance our understanding of school development and inform the next generation of interventions aimed at supporting ambitious teaching.

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Elham Kazemi
College of Education
University of Washington
USA