Scaffolding Into Ambitious Teaching: Representations of Practice in Teacher Workgroups

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Abstract: Teacher workgroups are increasingly mandated in policy as a strategy for instructional improvement, but without accounting for teacher learning. In this comparative case study, we take a situative view of learning to examine the learning opportunities afforded in workgroup meetings with middle-school math teachers and pedagogically expert facilitators. Using interaction analysis, we analyze the role of representations in affording learning opportunities. The facilitators framed workgroup activity differently than the teachers; learning opportunities were limited when teachers were not able to engage the facilitators' framings. But by introducing rich representations of practice, the facilitators attuned teachers' attention to key conceptual resources. This scaffolded the workgroup into new forms of practice, thereby supporting teachers' opportunities to learn more ambitious forms of professional practice. This work highlights the need for facilitators and instructional leaders to attend to issues of teacher learning in collaborative activity.

Keywords: teacher workgroups, representations of practice, framings, learning opportunities, ambitious instruction

Introduction

A substantial body of research has demonstrated that common approaches for teachers' professional development—e.g., short-term workshops—lack the power to transform instruction (Borko, 2004; S. M. Wilson & Berne, 1999). A promising proposal is to move professional development closer to teachers' practice (Ball & Cohen, 1999); one way to do this is through the development of teacher workgroups like content-based professional learning communities or grade-level planning teams. Teacher communities can support teachers' learning because they are embedded in school contexts and give teachers space to discuss problems of practice. Indeed, high correlations between strong teacher communities and greater-than-expected student achievement suggest that such communities are productive sites for teachers' learning (Bryk, Sebring, Allensworth, Easton, & Luppescu, 2010; McLaughlin & Talbert, 2001). This has led school leaders to mandate teacher communities as a mechanism for educational improvement. This strategy is often implemented under the assumption that if teachers have time and space to meet, then instructional improvement will happen (Little, 2003).

Many scholars have interrogated this assumption. They have identified aspects of workgroup activity—for example, participation structures (Horn, 2010) and epistemic stances (Hall & Horn, 2012)—that shape the nature of teachers' opportunities to learn. One endemic challenge for teacher workgroups is representing practice. Teachers typically discuss their work asynchronously from actual instruction, which makes it difficult for workgroup members to establish intersubjectivity. This drives the need for representations that adequately illustrate problems of practice (Hall & Horn, 2012).

Though other conversational features also shape teachers' learning opportunities in workgroup conversations, this study attends specifically to how representations of practice can be used in math teacher workgroups to support instructional improvement. We argue that participants can use representations of practice to attune others' attention to key conceptual resources, thereby scaffolding them into new ways of participating in workgroup activities. Teacher workgroups can thus become productive sites for instructional improvement as teachers are supported in engaging in more ambitious (Lampert, Boerst, & Graziani, 2011) forms of practice that support procedural fluency and conceptual understanding for all students.

Conceptual framework

We take a situated view of learning and define learning as a change in participation in a community of practice (Lave & Wenger, 1991). Since our analysis focuses on joint interaction, we view participation as presenting *opportunities* to learn (OTL) and refrain from making claims about individuals' learning. Following the work of Horn and colleagues {Hall:2012fg}, we operationalize OTLs by examining how interactions (a) marshal conceptual resources for teachers and (b) mobilize teachers for future work. In discussions with rich learning opportunities, teachers collectively develop concepts about pedagogical issues and connect these to their future

instruction. Such discussions afford learning opportunities as they position teachers to engage in new forms of professional practice.

Horn, Kane, and Wilson (2015) identified four interrelated conversational features that shape learning opportunities in teacher workgroup conversations: activity structures, frames, epistemic claims, and representations of instructional practice (Figure 1). These features are further shaped by the epistemic community and workplace culture they are situated in. Because of limited space, we describe the conversational features that are most relevant to this analysis, which are *frames* and *representations*; we refer the reader to Horn and colleagues (2015) for a fuller explanation of the other conversational features.

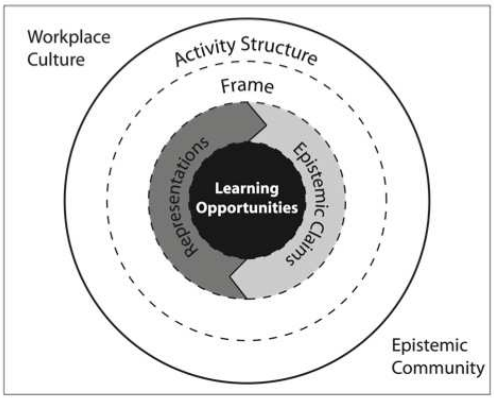

Figure 1. Conversational features that support learning opportunities (From Horn et al., 2015).

Frames refer to the ways that issues are defined in interaction (Goffman, 1974). The framings that participants employ shape the meaning of activities (Horn, 2007), changing what is salient in addressing problems of practice and thereby influencing learning opportunities. For instance, one teacher might frame a lesson-planning activity as a chance to identify questions for a whole-class discussion. A different teacher might frame the same activity as a chance to identify problems to include on a worksheet. These framings highlight different aspects of planning, and are thus consequential for OTLs.

Representations of practice refer to the ways that teachers make aspects of their teaching visible (Little, 2003). Common representations of practice include lesson plans, descriptions of past and future instruction (Horn, 2010), student work, and assessment data. Since workgroup conversations typically happen outside of instructional time, representations of practice support intersubjectivity in workgroup conversations, providing participants with a shared reference for their discussion.

We focus here on the relationship between *framings* and *representations of practice*. Participants in workgroup meetings may employ different framings of an activity, depending on their goals for the activity, their role in the meeting, and their level of expertise. On one hand, different framings may disrupt learning opportunities when participants do not negotiate shared meanings and instead talk past each other. On the other hand, different framings can support learning opportunities as teachers' ideas are negotiated, particularly when workgroups have a trusting culture (Horn, 2007) or "re-visioning" routines (Horn, 2010). In other words, workplace culture and conversational routines can be used to scaffold teachers into new forms of practice.

When participants are scaffolded into new forms of practice, they are operating in the *zone of proximal development* (ZPD) (Vygotsky, 1978/1997). The ZPD lies at the boundary between what a person can accomplish with scaffolding versus what they can accomplish on their own. Commensurate with our focus on joint interaction, we extend this definition to the group setting (Nyikos & Hashimoto, 1997). That is, a group's ZPD is the difference between what the group can accomplish with scaffolding and what the group can accomplish on its own. When the workgroup is scaffolded into new forms of practice—for example, by jointly engaging in a new way of lesson planning—the joint accomplishment constitutes an OTL for workgroup members because it affords changes to individuals' practice (Greeno & Gresalfi, 2008).

If participants in teacher workgroups employ different framings of activity, it can be difficult to establish joint interaction and collectively operate in the group's ZPD. Facilitators can attend to this issue by supporting teachers to engage the same framing. In this analysis, we address the following question: *How are representations of practice used to scaffold teachers' participation in workgroup conversations?* Our central claim is that facilitators can leverage representations of practice to scaffold workgroups in new ways of participating in activities. The use of representations of practice as a scaffold is particularly salient when teachers and facilitators employ different framings of an activity.

Methods

Research context

The data under analysis come from an eight-year design-research study of how districts support improvement of mathematics instruction at scale (Cobb, Jackson, Smith, Sorum, & Henrick, 2013). Beginning in 2007, our team purposively sampled four large, urban districts for their commitment to improve the quality of middle-school mathematics instruction. Within each district, schools were sampled representatively with respect to their capacity for instructional improvement. In order to study teachers' learning opportunities, we selected teacher workgroups for close study based on the presence of a catalyst for teachers' learning (e.g., individuals with pedagogical expertise or other unusual resources). We conjectured that such catalysts would spark additional opportunities for teachers to learn about improving their instruction. The focal workgroups in this study were selected for their facilitators' unusual mathematics and pedagogical expertise.

Data and analysis

The data analyzed in this study come from videotaped meetings of two focal workgroups at different middle schools in the same district. The first focal group consisted of the 7th-grade math teachers at Silver Pond Middle School: Ngozi, Maria, and Peter (all proper names are pseudonyms). Jane Shepley, a school-based instructional coach and former math teacher, facilitated these meetings. Over the course of two meetings, teachers planned and debriefed a lesson on proportional reasoning. The second focal group consisted of the 6th-grade math teachers at Riverview Middle School (Rachel, Crystal, and Devon). Principal Vera Cardwell, a former math teacher and instructional coach, facilitated these meetings. During these sessions, teachers used data from a mid-year assessment to plan instruction.

The facilitators for each of these focal groups, Jane and Vera, demonstrated unusually high mathematical and pedagogical expertise. Both were middle school mathematics teachers (for 6 and 10 years, respectively) and had experience supporting math teachers as instructional leaders (for 8 and 6 years). In interviews, they also described ambitious visions of high-quality math instruction (Munter, 2014) and expressed goals for supporting teachers' learning to improve their practice. The teachers in each focal group, however, demonstrated moderate mathematical and pedagogical expertise. They tended to engage in traditional forms of instruction as measured by the Instructional Quality Assessment (Boston & Wolf, 2005) and described less-ambitious visions of high-quality math instruction than their facilitators. We characterize both workgroups as cases in which we expect to see rich learning opportunities because of the expertise of the facilitators.

Qualitative analysis

Our primary unit of analysis is an episode of pedagogical reasoning (EPR; Horn, 2007). We define EPRs as topically-bounded units of talk where participants reason about an issue of instruction. We first identified EPRs within each workgroup's meetings. We then noted that some EPRs afforded richer OTLs than others (Horn & Kane, 2015). Using multimodal interaction analysis (Jordan & Henderson, 1995), we analyzed OTLs, paying attention to the conversational features available: activity structures, frames, epistemic claims, and representations of practice (Figure 1). In many EPRs, the teachers and facilitators employed different frames as they engaged in workgroup activities. Across these episodes, we noted that there was wide variation in learning opportunities; we examined patterns of other conversational features to explain this phenomenon.

Findings

In the episodes excerpted below, we illustrate how facilitators drew on representations of practice to scaffold teachers into more ambitious forms of participation. In all four episodes, the facilitators' framings emphasized the importance of attending to students' thinking. In EPRs 1 and 3, the teachers' learning opportunities were limited by different framings and inadequate representations. However, in EPRs 2 and 4, stronger representations of practice were used to scaffold teachers to engage with the facilitator's framings.

EPR 1: Misaligned framing for lesson planning

EPR 1 illustrates the limited learning opportunities that can occur when participants employ different framings. At Silver Pond, Jane led the 7th-grade math teachers in planning the "Orangey" task, a lesson on proportional reasoning (Lappan, Fey, Fitzgerald, Friel, & Phillips, 2009). The task asks students to compare different mixtures of water and orange juice concentrate (e.g., Mixes A, B, C, and D; Figure 2) to decide which mixture is most "orangey."

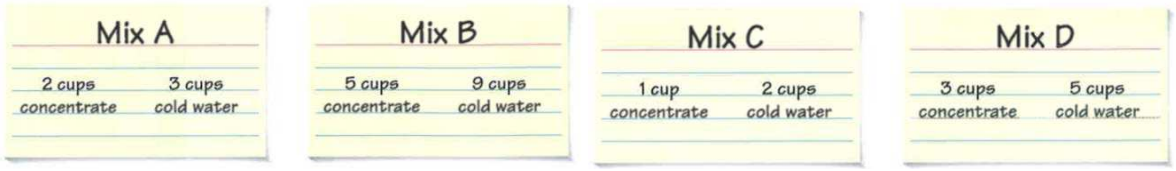

Figure 2. The "Orangey" task from the Connected Math Project (Lappan et al., 2009).

Jane suggested that the teachers introduce the task by having students taste undiluted concentrate. By introducing the task in this way, teachers would elicit students' understanding of the contextual features of the task—what is meant by "orangey." Jane asserted this framing in Turn 1.1 (framings underlined for emphasis throughout), drawing attention to the pedagogical function of the "launch" or introduction: to prepare students to engage in the mathematical work of the task (Jackson, Shahan, Gibbons, & Cobb, 2012).

1.1 Jane: By letting 'em taste. They're like [*makes sour face*] That'll help them think about what a concentrate is. And then, move into the discussion of "What is the process to make this drinkable? We have to start adding water. How much water do we need to add?" Well, these students did this, this, this, and this. Is that gonna be enough of a launch to get us to where they need to be in order to solve the questions that we've already, well, we know they're gonna end up having to do? What you think?

Jane's framing of the launch emphasized helping students understand the contextual features of the task as a way of preparing them to engage in the pending mathematical task. Framed in this way, the launch is an important aspect of ambitious teaching as it supports all students to engage in mathematics by lowering barriers for participation. However, the teachers employed a framing that emphasized logistical concerns:

1.2 Ngozi: Um, really by time they make up these mixtures in real life, it takes a lot of time. Because then, everybody wants to go through each station to taste because then, the colors are gonna look the same because they don't taste it.

1.3 Jane: Okay.

1.4 Ngozi: So, what I would suggest or what I did in the past was we, probably, this is like a reward. This is our after thing.

Ngozi's response to Jane's questions asserted a framing that emphasized logistical concerns. Instead of letting students taste mixtures or the concentrate as part of the launch (which "takes a lot of time"), Ngozi suggested that it become a "reward" activity to do after the main lesson. This framing fundamentally shifts the meaning of the planning activity by emphasizing logistics over student thinking.

Jane responded by reasserting a framing that emphasized preparing students for the mathematical task by familiarizing them with its contextual features. She clarified her proposal: kids should get a small taste of the concentrate "so that they know what [concentrate] means and what that is." However, the other teachers engaged with Ngozi's framing, raising additional logistical concerns like whether diabetic students should taste the concentrate or what brand of concentrate they should buy.

Taken together, these data illustrate a misalignment between the framings employed by Jane and the teachers. Though Jane consistently pressed the teachers to attend to pedagogical concerns, the teachers consistently responded with logistical concerns. The teachers raised valid issues—certainly, students' health and efficient use of time are important—but their responses shifted the meaning of the activity in ways that were unlikely to lead to instructional improvement. We saw this pattern throughout many of the Silver Pond's 7th grade planning meetings. This limited the workgroup's participation in a new form of lesson planning that actively anticipates students' understanding of the contextual features of tasks.

EPR 2: Using student work as a scaffold into ambitious practice

Whereas EPR 1 showed how misaligned framings can disrupt teachers' learning opportunities, EPR 2 illustrates how representations of practice can be used to overcome misalignment and scaffold a workgroup's participation in forms of practice that lie in its ZPD. A few days after the planning meeting described in EPR 1, the Silver Pond teachers taught the Orangey task; during the meeting described here, they debriefed the lesson. Consistent with the framing she employed in EPR 1, Jane asked the teachers to reflect on whether the introductory activities (e.g., the launch) were "enough to tell if our students were ready" to successfully participate in the mathematical task.

Initially, teachers gave superficial replays (Horn, 2010) of instruction that elided students' contributions. Unsatisfied with their responses, Jane reasserted her framing and drew teachers' attention to a concrete representation of practice: posters of student work.

2.3 Jane: We want to look at this work using the lens of a teacher. What does it tell me, and what do I need to do moving forward? Let's take a few minutes to look at the work samples, and see if we're ready to move forward. [*teachers turn to face student work*] Do we need to remediate? Reteach something? [*walks toward posters, gestures to them*]

In this turn, Jane used the framing of "the lens of a teacher," highlighting the importance of interpreting students' work before planning future instruction. Once attuned to the representations of student thinking, the teachers took up Jane's framing and focused on discerning what students understood about their solution strategies. Figure 3 shows one student group's solution. Maria noted that the students found a common denominator for 3, 9, 2, and 5 and scaled up each ratio to a denominator of 90. Ngozi agreed and then extended Maria's observation, wondering whether her students understood how they were comparing the ratios:

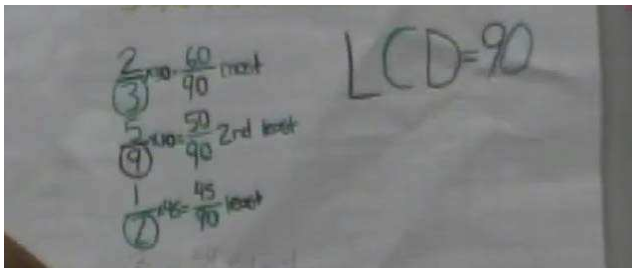

Figure 3. Poster showing students' solution strategy for comparing the ratios 2:3, 5:9, 1:2, and 3:5 (not shown).

2.8 Ngozi: Yeah. They got the same number of cups of water, but do my students know that? I don't know.

2.9 Jane: That's a good question.

2.10 Maria: They categorized them. Which one was the most.

2.11 Jane: She's saying, do they understand that when they scaled up here—

2.12 Maria: Why did they do it?

2.13 Jane: When they scaled up, do they notice that they all have the same number of cups of water, and the one that I'm picking has the most cups of concentrate.

In this exchange, Jane ratified and encouraged the workgroup's sensemaking. Through their line of inquiry (Turns 2.8, 2.12), Ngozi and Maria engaged Jane's framing of the activity. They went on to discuss whether students knew they were using a part-to-part comparison (i.e., concentrate to water, as opposed to concentrate to total volume). The teachers then prepared for future work by rehearsing (Horn, 2010) questions to ask students in upcoming lessons. Ngozi further clarified that she would "expect them to say concentrate/water." Jane agreed, gesturing at the posters and wondering, "So do they know what this stuff is?"

In this EPR, teachers used representations of practice (i.e., student work) to make inferences about students' understanding. In doing so, they jointly participated in the activity of lesson debriefing in a way that engaged Jane's framing. Alternatively, one might conjecture that this form of participation can be attributed to the fact that the teachers frame planning and debriefing differently. Yet in other meetings, the workgroup participated in debriefing activities without adequate representations, and the teachers' engaged framings that emphasized logistical concerns. We argue that joint participation in the activity of debriefing (EPR 2) was fundamentally altered by the group's use of representationally adequate artifacts of student thinking. The posters of student work scaffolded the workgroup's participation in new forms of debriefing that were in the group's ZPD. This participation constituted learning opportunities for teachers that support instructional improvement.

EPR 3: Inadequate framing for data use

Our third EPR took place at Riverview during a meeting to discuss data from a multiple-choice assessment. Vera, the principal, provided teachers with a variety of representations, including a list of assessment items showing the percentage of students that answered each item correctly, the distribution of students' responses on each item,

copies of the assessment, copies of the state math standards, and a lesson planning template. To start the meeting, Vera framed the activity by telling teachers to use assessment data to plan instruction:

> Vera: Look at the item, study the [standard], what part of the [standard] was addressed, what did kids struggle with, BAM, that's your finding.

In this short sentence, Vera framed a sophisticated data use process that emphasized determining student thinking ("what did kids struggle with") to design an instructional response ("your finding") to support student learning. To participate fully in this practice, teachers needed to synthesize across a variety of representations to interpret how students may have approached assessment items on many different mathematical concepts.

As the teachers began analyzing data, they engaged with Vera's framing of the activity. They began this episode by identifying an item that students did poorly on. The standard (fraction, decimal, and percent conversion) is "one that [students] are still struggling on," according to Devon. He told Crystal to read the item:

> 3.5 Crystal: "Jeremy bought a skateboard on sale for $28, which was 12.5% off the original price. What was the discount as a fraction of the total price?" Well all they need to know is the 12 and a half percent.
>
> 3.6 Devon: The majority of students chose B. [12/5]
>
> 3.7 Crystal: Why?
>
> 3.8 Devon: 12 over 5
>
> 3.9 Crystal: That's crazy
>
> 3.10 Rachel: All they did was take the numbers and—that makes me mad *[laughs]*

Though the teachers engaged in Vera's framing of the data use activity—they looked at the item, the standard, and how students responded to it—their explanation for the source of students' difficulties was not strongly linked to students' mathematical thinking or issues of instruction. Crystal went on to say that the students "are not confident, and they don't know it." Rachel concluded that "We need to do some problems with a percent that has a decimal in it" before moving on to consider other test items. This instructional response (providing more practice problems) is unlikely to support more ambitious forms of instruction that address students' conceptual understandings of fraction, decimal, and percent relationships.

The Riverview teachers had many material representations available to analyze assessment data, but were not able to participate in more ambitious forms of data use. They engaged with a thin, almost mechanistic version of activity as Vera framed it. Admittedly, this framing was described in vague and general terms; Vera did not specify what it meant to "look" at an item or how to determine what "kids struggled with." We argue that her framing was insufficient to scaffold teachers into new forms of practice. Furthermore, the representations of student learning available to the Riverview teachers (tables of assessment data) were distal to instructional practice, particularly when compared to the representations available in EPR 2 (posters of student work). This made it more challenging for teachers to plan future instruction in ways that accounted for student thinking. Therefore, participation in ambitious data use practices was limited in this conceptually sparce space.

Episode 4: Coordinating evidence to scaffold participation

In EPR 4, Vera joined the teachers' conversation and provided additional representational resources that scaffolded the workgroup's participation into more sophisticated data use practices. She elaborated on her framing—much like Jane's elaboration on "using the lens of a teacher" in EPR 2—by modeling her method of data use and coordinating multiple representations of practice as evidence of student thinking.

Devon asked Vera to review the same assessment item the teachers examined in EPR 3. When Vera joined the conversation, she immediately asked a series of questions to orient herself, identifying the standard, the item, teachers' instructional approaches, and the most commonly selected answer choices. Much of this paralleled the workgroup's discussion above. But as Vera interpreted the data, she added additional representations of practice (replays and rehearsals) to connect the material representations to instruction:

> 4.31 Vera: Okay, so I would say, then, this is probably, I mean, my gut it could be a combination of the .5, however, I, it's probably rooted in the question.
>
> 4.32 Crystal: I thought, that's what I thought, because
>
> 4.33 Vera: You know what I mean? They didn't realize that you were finding the equivalent form of a number. They might even try to

4.34 Crystal: Do something with the 28, they don't know how to omit the non-necessary information

Vera considered multiple sources of student misunderstanding; she acknowledged that both the decimal in the percent (i.e., 12.5% as opposed to 12%) and the wording of the question may have been difficult for students (Turn 4.31). Crystal elaborated on Vera's explanation, suggesting that students "don't know how to omit the non-necessary information" (Turn 4.34). However, Rachel pushed back, asserting that "they have not dealt with decimals in percents enough." Vera then offered a rehearsal of a way to solicit more evidence about students' understanding (Turn 4.37) and supported it with a replay of her own instruction (Turn 4.39):

4.37 Vera: So what I would ask them, then, if you want to deduce that right? And you want, you know, to determine that that definitely is, then the best way is to have every kid take okay, 12.5%, represent it as a fraction. Take all the words out.

4.38 Rachel: Mmhmm. And they don't know how to do that.

4.39 Vera: And that, and that will tell you immediately whether or not that was one of the layers of problem. But I know when we we talked about, um, an-an-and those are common ones that we usually go over? Like, okay, when I was a 6th grade teacher, at this point in the time, I don't know if I would say that that was overwhelmingly all of my kids' issues. Because, I had a chart they filled out every single day, like, starting in January, that showed 12.5, I want it as a fraction, I want a decimal, you know, I want it as uh, uh, a percent, or whatever, my conversions. So we would include those.

In this exchange, Vera built a nuanced representation of multiple ways in which students may have approached the test item. She drew upon conceptual representations of instruction (replays and rehearsals) to augment and connect to physical representations of student learning. When Rachel re-asserted concerns about the decimal in the percent, Vera used the rehearsals (Turns 37, 39) to scaffold the workgroups' participation in developing an alternate instructional response that addressed multiple "layers of problem." By using conceptual representations of practice (replays and rehearsals) to augment thin physical representations of practice (tables of assessment data), Vera scaffolded the workgroup into more ambitious forms of data use practice and mobilized the teachers for future instruction that accounted for students' thinking.

Conclusions and implications

Across these episodes, we see that misaligned or inadequate framings of workgroup activities can disrupt teachers' opportunities to learn more ambitious forms of practice (EPRs 1, 3). However, facilitators can leverage representations of practice to scaffold teacher workgroups into forms of participation that are within the group's ZPD (EPRs 2, 4). As workgroups engage in new forms of practice, participants can develop concepts of pedagogy and prepare to engage in more ambitious instruction that attends to students' mathematical thinking. Thus, representations of practice can serve as a resource for teacher workgroups to use in efforts to improve instruction.

This study builds on previous literature that has shown how certain workgroup features, like workgroup culture (Horn, 2007) or conversational routines (Horn & Little, 2010), can be used to support teachers' learning opportunities in workgroups where participants employ different framings. When these conversational features align (i.e., afford the same goals of the activity), workgroups can engage in new forms of practice. When there is misalignment across the conversational features learning opportunities are significantly more limited.

This work has important implications for the development of teacher workgroups as sites for professional learning. In particular, facilitators must attend to issues of teacher learning in collaborative activity. Facilitators can support teachers' learning opportunities by framing workgroup activities in terms of ambitious mathematics instruction (e.g., considering student thinking in planning for instruction), and representations of practice can serve as key supports to attune teachers' attention to issues of pedagogy and to scaffold workgroups' engagement in new forms of practice. Future work is needed to investigate how to support facilitators to (a) recognize when workgroup participants employ framings that are not aligned with goals for instructional improvement and (b) employ activity structures and conversational features that can scaffold workgroups into more ambitious forms of practice.

References

Ball, D. L., & Cohen, D. (1999). Developing Practice, Developing Practitioners: toward a practice-based theory

of professional education. In G. Sykes & L. Darling-Hammond, *Teaching as the learning profession: Handbook of policy and practice* (pp. 3–32). San Francisco: Jossey Bass.
Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3–15.
Boston, M., & Wolf, M. K. (2005). *Assessing Academic Rigor in Mathematics Instruction*. Center for the Study of Evaluation, National center for Research on Evaluation, Standards, and Student Testing.
Bryk, A. S., Sebring, P. B., Allensworth, E., Easton, J. Q., & Luppescu, S. (2010). *Organizing Schools for Improvement*. University of Chicago Press.
Cobb, P., Jackson, K., Smith, T., Sorum, M., & Henrick, E. (2013). Design research with educational systems: Investigating and supporting improvements in the quality of mathematics teaching and learning at scale. In W. Penuel, B. J. Fishman, & B. H. Cheng, *National Society for the Study of Education Yearbook on Design-Based Implementation Research*.
Goffman, E. (1974). *Frame analysis: An essay on the organization of experience.* Harvard University Press.
Greeno, J. G., & Gresalfi, M. S. (2008). Opportunities to Learn in Practice and Identity. In Assessment, Equity, and Opportunity to Learn. Cambridge University Press.
Hall, R., & Horn, I. S. (2012). Talk and Conceptual Change at Work: Adequate Representation and Epistemic Stance in a Comparative Analysis of Statistical Consulting and Teacher Workgroups. Mind, Culture, and Activity, 19(3), 240–258. doi:10.1080/10749039.2012.688233
Horn, I. S. (2007). Fast kids, slow kids, lazy kids: Framing the mismatch problem in mathematics teachers' conversations. The Journal of the Learning Sciences, 16(1), 37–79.
Horn, I. S. (2010). Teaching replays, teaching rehearsals, and re-visions of practice: Learning from colleagues in a mathematics teacher community. The Teachers College Record, 112(1).
Horn, I. S., & Little, J. W. (2010). Attending to Problems of Practice: Routines and Resources for Professional Learning in Teachers' Workplace Interactions. American Educational Research Journal, 47(1), 181–217. doi:10.3102/0002831209345158
Horn, I. S., & Kane, B. D. (2015). Opportunities for Professional Learning in Mathematics Teacher Workgroup Conversations: Relationships to Instructional Expertise. Journal of the Learning Sciences, 24(3), 150415095906006. doi:10.1080/10508406.2015.1034865
Horn, I. S., Kane, B. D., & Wilson, J. (2015). Making Sense of Student Performance Data: Data Use Logics and Mathematics Teachers' Learning Opportunities. American Educational Research Journal, 52(2), 208–242. doi:10.3102/0002831215573773
Jackson, K. J., Shahan, E. C., Gibbons, L. K., & Cobb, P. A. (2012). Launching complex tasks. *Mathematics Teaching in the Middle School*, *18*(1), 24-29.
Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. The Journal of the Learning Sciences, 4(1), 39–103.
Lampert, M., Boerst, T. A., & Graziani, F. (2011). Organizational resources in the service of school-wide ambitious teaching practice. *The Teachers College Record*, *113*(7), 1361–1400.
Lappan, G., Fey, J. T., Fitzgerald, W., Friel, S., & Phillips, B. (2009). *Comparing and Scaling: Ratio, proportion, and percent*. Boston, MA: Pearson.
Little, J. (2003). Inside teacher community: Representations of classroom practice. *The Teachers College Record*.
McLaughlin, M. W., & Talbert, J. E. (2001). *Professional Communities and the Work of High School Teaching*. University of Chicago Press.
Munter, C. (2014). Developing Visions of High-Quality Mathematics Instruction. *Journal for Research in Mathematics Education*, *45*(5), 584–635.
Nyikos, M., & Hashimoto, R. (1997). Constructivist Theory Applied to Collaborative Learning in Teacher Education: In Search of ZPD. The Modern Language Journal, 81(4), 506–517.
Supovitz, J. (2012). Getting at Student Understanding–The Key to Teachers' Use of Test Data. *Teachers College Record*, *114*, 1–29.
Vygotsky, L. (1997). 4: Interaction Between Learning and Development. In *Readings on the Development of Children* (pp. 1–9). Macmillan.
Wilson, S. M., & Berne, J. (1999). Teacher Learning and the Acquisition of Professional Knowledge: An Examination of Research on Contemporary Professional Development. *Review of Research in Education*, *24*, 173–209.

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