RECONCILING LOCAL CONTEXTS AND EXTERNAL CONCEPTUAL RESOURCES IN MATHEMATICS TEACHERS' COLLABORATIVE SENSEMAKING

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Mathematics teachers develop understandings about instruction across multiple settings, such as classrooms, workshops, and professional learning communities. When teacher teams collaborate, their prior teaching and learning experiences meaningfully inform their sensemaking. However, current research does not explicitly link teacher conversations and these multiple settings for learning. In this study, we seek to understand secondary mathematics teachers' collaborative learning in schools as part of broader teacher learning ecologies. Using discourse analysis and a comparative case study design, we examine how two teacher teams' conversations recruit external conceptual resources to support the development of their collective pedagogical judgment. In particular, these external resources offered the teams rich representations of practice and productive framings of teaching problems.

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In a recent review of research on teacher collaborative discourse, Lefstein and colleagues (2019) noted that researchers in this nascent field rarely attend to broader contexts of teacher conversations; "rather, they primarily focus on the immediate context of the setting or intervention" (p. 6). This stands in sharp contrast to calls to develop theory and methods to study teacher learning as distributed across contexts (e.g., Kazemi & Hubbard, 2008). For example, consider Borko's (2004) AERA presidential address:

> For teachers, learning occurs in many different aspects of practice, including their classrooms, their school communities, and professional development courses or workshops. It can occur in a brief hallway conversation with a colleague, or after school when counseling a troubled child. To understand teacher learning, we must study it within these multiple contexts, taking into account both the individual teacher-learners and the social systems in which they are participants. (p. 4)

Borko's call resonates with the PME-NA Conference's theme of "manifestations across different cultures, places and contexts," pointing to the need to develop tools to look across contexts for making sense of learning. It also aligns with our own experience as teacher educators (Buenrostro & Ehrenfeld, 2019; Marshall & Horn, under review) and our overall goal to develop better ways to design, facilitate, and analyze teacher collaboration toward improved mathematics instruction.

For the past four years, we have been supporting teacher learning through conversations with mathematics teacher teams in their schools. In these conversations, we noticed that teachers often build their ideas on what we refer to as external conceptual resources. We define external conceptual resources as frameworks, tools, and concepts that transcend different teacher learning environments, which are external to the local school context and echo voices external to the local team. Examples of such resources include teaching practices from workshops, curricula from previous schools, or teaching strategies introduced at a conference.

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We have multiple motivations for looking at mathematics teacher learning across contexts. First, calls to study teacher learning across multiple contexts (e.g., Borko, 2004; Kazemi & Hubbard, 2008; Lefstein et al., 2019) coincide with recent moves in the learning sciences away from seeing learning as tied to specific places to learning that is distributed across environments — multiple settings for individuals' sensemaking that are sometimes referred to as learning ecologies (Barron & Bell, 2016). When they are invoked, external conceptual resources often echo voices from these other contexts; by attending to them in our analysis, we offer a method to study teacher conversations as they are embedded in broader learning ecologies. Second, we think there is practical value in analyzing the particular role of external conceptual resources in mathematics teachers' collaborative sensemaking; understanding how teachers recruit these resources in their sensemaking can illuminate productive ways to design things like professional development, curricular tools, and analytic frameworks for teaching with the goal of supporting their productive use in schools and classrooms. Thus, our main goal in this study is to better understand how external conceptual resources contribute to mathematics teacher collaborative sensemaking.

Theoretical Framework: A Situative View on Teaching and Teacher-Learning

We take a situative perspective on mathematics teachers' learning which supports investigations into activity systems and contexts that shape meanings (Borko, 2004; Greeno, 1998; Horn & Kane, 2015). Teachers constantly make sense of pedagogies and educational reforms in the context of their classrooms and amidst wider socio-historical forces (Coburn, 2001; Horn & Little, 2010). For example, Marshall & Horn (under review) found teachers' uptake of learning from professional development (PD) workshops is largely influenced by the goals and demands in their local teaching situations. As mathematics teacher educators, we aim to design environments that present teachers with opportunities to learn (OTLs) which, in turn, will support their instruction.

To study mathematics teachers' OTLs in conversations about instruction, we follow Horn & Kane (2015) who emphasize how rich conceptual resources support rich OTLs. In previous analyses of conceptual resources in teacher conversations, researchers attend to teachers' representations of practice and productive frames for problems of practice as being consequential in how teachers make sense of and improve instruction (Bannister, 2018; Brasel et al., 2016; Hall & Horn, 2012; Horn & Kane, 2015; Vedder-Weiss et al., 2018). Representational infrastructures are "technologies, ways of talking, and materials that support how people engage with conceptual practices in their activity" (Hall & Jurow, 2015, p. 174). Representations of practice are a part of these infrastructures that make different aspects of teaching more or less visible (Little, 2003), and they are critical for considering alternative ways of working in the future (Hall & Horn, 2012). Framing is a discursive process by which meanings are generated by participants to imply what are relevant and legitimate ways of understanding and discussing a situation (Goffman, 1974). Vedder-Weiss and colleagues (2018) argue that productive, collaborative framing of problems of practice links teaching, learning, and subject-matter, creates opportunities to rethink practices, and positions teachers as having the power, authority and responsibility to cope with the problem. Bannister (2018) underscores that looking at collaborative problem frames is a useful analytic tool both in identifying problems (diagnostic frames) of practice and in suggesting solutions (prognostic frames). In this study we contribute to the research of conceptual resources in mathematics teacher conversations by investigating how, through teachers' references, external conceptual resources have the potential to support both rich representations and productive framing of practice, which in turn can provide the collaborative team with rich learning opportunities.

In our analysis of teacher learning, we draw on Horn's (2020) conception of teacher learning as the development of pedagogical judgment to inform our research question: How do external conceptual resources contribute to teachers' pedagogical judgment? In our work, pedagogical judgment consists

of three interrelated but analytically distinct components: (1) pedagogical action: choices teachers make, intentional or not; (2) pedagogical reasoning: different interpretations and rationales supporting actions; and (3) pedagogical responsibility: teachers' sense of ethical or situational obligations. In this analysis, we look for evidence of teachers' efforts towards the alignment of these three components during their development of pedagogical judgement.

Data and Methods

Research Context and Data

To investigate the role of external resources in mathematics teachers' collaborative sensemaking, we use data from a larger research-practice partnership between our research team and a professional development organization (PDO) for secondary mathematics teachers, where we designed a system for video-based feedback on teachers' instruction. We facilitated and filmed 33 cycles of classroom observations followed by a lesson-debrief conversations with teacher teams in their schools, organized around videos of teachers' classrooms. The primary goal was to use the classroom video to elicit, engage, and develop secondary math teachers' pedagogical judgment.

Data Analysis

Phase 1: Conceptualizing teacher conversations as part of a larger teacher learning ecology and selecting cases. During our analysis of the lesson-debrief conversations, we noticed that teachers often built their ideas on the external conceptual resources we defined earlier. Our primary units of analysis were episodes of pedagogical reasoning (EPRs), which are segments of conversation participants reason about an issue of instruction (Horn, 2007). We created an inventory of EPRs in which we noted what, when, where, and by whom such resources were referenced. In building this inventory of EPRs, we started to better understand how the debrief conversations are discursively connected to other settings in the larger teacher learning ecologies (see Figure 1). For this paper, we chose to analyze cases around two conceptual resources from contexts often mentioned in teacher conversations: experiences in previous schools and workshops. We selected these two cases from Noether High School and Rees Middle School (see Table 1, all names of schools and teachers are pseudonyms) because they provide exceptionally illuminating examples of ways teachers reason with and about external conceptual resources in their respective local contexts.

Table 1: School Context Summary

School	Student Demographics	Debrief Participants
Noether High School	60% Latinx, 15% African/African American, 15% Asian/Asian American, 10% White, 5% Filipinx	Teachers: Brad (filmed), Marisa and Greg. Researchers: Lani and Nadav
Rees Middle School	80% Latinx, 5% Asian, 5% White, 5% Filipinx, 5% African/African American	Teachers: Ezio (filmed) and Veronica. Researchers: Patty, Lani and Nadav

Phase 2: Analyzing the intersection of local contexts and external conceptual resources. Using interaction analysis methods (Jordan & Henderson, 1995), we looked closely at videos of each of the two debrief episodes. To pursue our overarching research question, we asked a number of sub questions that allowed us to understand the meanings the teachers were negotiating and (re)constructing; these questions included: How are the resources referenced in teachers' conversations? How are they taken up (possibly with transformations) by other participants (Goodwin, 2018)? How do they support reasoning about teachers' goals and responsibilities (Horn,

2020)? How do they offer (or not) adequate representations of practice (Hall & Horn, 2012; Little, 2003) and productive problem framings (Bannister, 2018; Vedder-Weiss et al., 2018)?

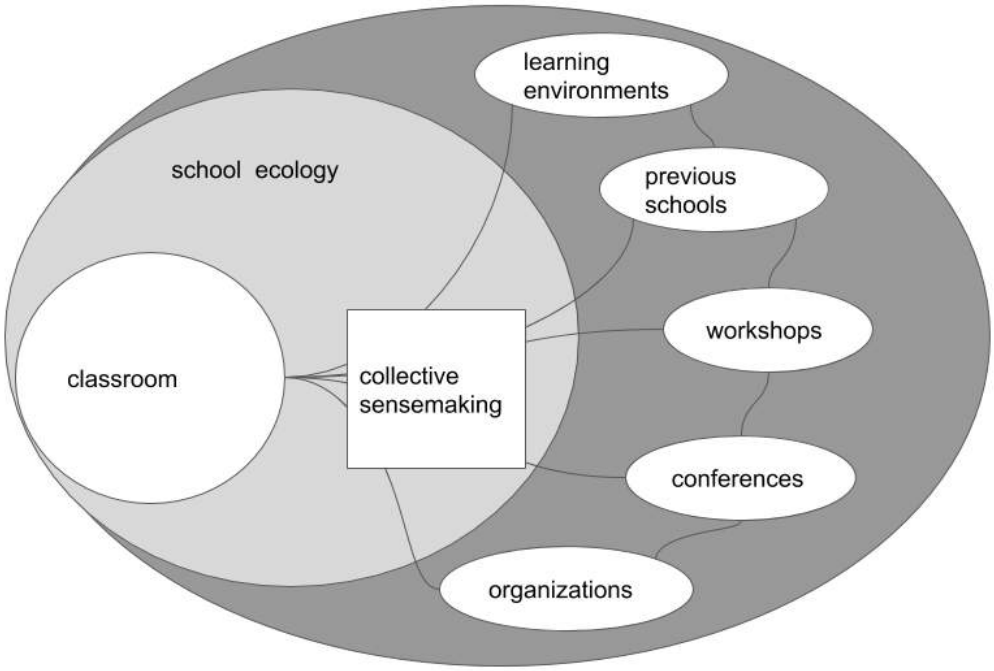

Figure 1: A Schematic Representation of Collective Sensemaking as Part of Teacher Learning Ecologies

Findings: Honing Pedagogical Judgment by Reconciling Local Contexts and External Conceptual Resources

In the focal debrief conversations, external conceptual resources supported the development of teachers' pedagogical judgment by affording richer representational infrastructure and more productive problem frames, which in turn increased alignment among teachers' pedagogical action, reasoning, and responsibility. We illustrate this process in the following cases, where teachers collectively reconciled local problems of practice by mobilizing external resources for their sensemaking. Table 2 summarizes the two cases.

Table 2: Case Studies Summary

External Conceptual Resource	Recruited From...	Local Context	Afforded...
College Preparatory Math (CPM) curriculum	Marisa's previous school	Noether debrief conversation May 2018	representation of teaching as establishing learning environment. framing of the problem of students' mathematical agency around processes of building classroom culture.

Random Grouping and Purposeful Grouping as instructional practices	Park City Mathematics Institute (PCMI) workshop and Kagan training	Rees debrief conversation December 2017	representation of teaching as entailing judgments between contrasting structures. framing the problem of labeling students by underscoring local school context and teacher agency.

EPR 1: Representation and Framing of the Problem of Leveraging Students Agency

The first case is of a debrief conversation at Noether High School. After filming Brad's Algebra 1 classroom, we returned to debrief the lesson with him and his school-based team consisting of Brad, Marisa, and Greg. We introduced clips from this lesson to discuss Brad's topic of interest which was the way he provides feedback to students. The first clip featured Brad giving a group of students a strong cue about how to proceed with the problem. Following Brad's comment "I wonder if there's a better question that I could have asked" the research team and teachers in the debrief then suggested alternative interactions that would promote more independent student thinking. For example, Greg suggested "why do you think that?" and Marisa suggested "how did you figure that out?" as alternative responses. Important to our analysis is that at this point, the conversation was focused on illustrations of teacher-student interactions, and that the team was motivated by a shared responsibility to leverage students' mathematical agency.

Problem-based curriculum as an external resource. After some comments about the content of the task, Marisa referenced her experience of teaching a problem-based curriculum, College Preparatory Math (CPM), in her previous school:

> I'm looking forward to hmm possibly next year having a problem-based curric- well, I don't know if we're going to teach geometry- what we're going to teach, but if we do teach geometry, if we could possibly use the CPM curriculum because one of the reasons I like that particular curriculum is because it's in groups from day one. Every day students are working in groups. That's the culture of the classroom that's built up. So, they're creating the meaning from doing the problems and developing the mathematics by the problem solving that they're doing and the teacher's kind of just there facilitating and you're walking around the whole time asking the questions and guiding if they need it, but it's all coming from the students all the time.

Marisa describes her experience in a classroom where students have mathematical agency and see themselves and their peers as resources of mathematical knowledge. She attributes it to the problem-based curriculum, but more specifically to the structures (such as working every day in groups) that contribute to a collaborative classroom culture. Marisa then contrasted this experience with their current classrooms' situation, where they are "going kind of back and forth" between direct instruction and groupwork. She perceived that students in their current classrooms get frustrated when teachers don't hand over answers, as in her narration of students saying—"well, just tell me, just tell me what it is." The episode ended with others acknowledging that the problem involves the disruption of traditional classroom norms, and that even with a problem-based curriculum, students are always "going to struggle the first time" (Greg).

Representation and framing. In the Noether team's debrief, the teachers discussed the focal teacher, Brad's, groupwork facilitation and ways to leverage students' agency and communication. The representation of teaching made visible in this episode began with a focus on teacher-student interactions. Then, Marisa shared her previous experience of teaching the CPM curriculum. Drawing on the external conceptual resource of CPM, Marisa supplemented this representation of teaching

with aspects of designing a learning environment and reframed the problem of practice from the particularities of the teaching interactions (micro) to the construction of a certain classroom culture (macro). We see the new frame as productive in that it moved the conversation away from the problem frame of leveraging students' agency as transient and technical and yet still positioned the teachers as having the power to address it.

Pedagogical judgment. Implicit in this reframing is Marisa's reasoning that to leverage students' mathematical agency, teachers' differing responses is not enough; teachers need to engage in a more macro pedagogical action, in this case setting collaborative classroom norms from the first day. This frame offered the team images of new actions that support students' mathematical agency. We argue that Marisa's experience in her previous school with the CPM curriculum was a meaningful external resource for learning in this conversation; CPM was not used as a resource to reason about CPM. Teachers in conversation were not trying to teach CPM as a new curriculum; rather, they reasoned with CPM about groupwork facilitation, towards a better alignment of the team's pedagogical actions with their pedagogical responsibilities.

EPR 2: Representation and Framing of the Problem of Labeling Students

The second case comes from a debrief conversation at Rees Middle School. We filmed Ezio's classroom and returned after a few days to debrief the lesson with him and his colleague Veronica. We introduced clips from this lesson to discuss Ezio's topic of interest which was group dynamics. Ezio's lesson objective was to help students distinguish between linear and nonlinear equations, and he structured his 90 minutes lesson around two group tasks. Students were randomly assigned to groups of three. After listening to some student conversations in the debrief, Ezio became concerned that not all students were contributing to their group conversations, and we discussed whether providing more structure might have helped students work more productively together. For example, Ezio mentioned a structure where the student holding the marker can't talk, and Veronica wondered if group roles would have been helpful.

Random and purposeful grouping as external resources. At this point, a member of the research team (Patty) prompted the teachers to elaborate on their understanding of group dynamics. Ezio responded by initially distancing himself from the practice of random grouping used at PCMI: "at least in PCMI, I really did not agree with the random grouping." Veronica pressed him on this, saying, "But you are doing random grouping." He confirmed that he was:

Ezio:	Yeah. I let the computer pick it out. I've been trying it out. We got Kagan training
Patty:	mm-hmm
Ezio:	a couple years ago and at least what they said made sense, where it's purposeful—
Veronica:	Purposeful grouping.
Ezio:	Yeah, like a high low—
Patty:	Yep.
Ezio:	There was a structure to everything. and uh—
Patty:	so you're wondering if—
Ezio:	I was wondering, I didn't agree with PCMI but I wanted to try it out to see.
Patty:	Okay

Ezio repeated twice how he first did not agree with random grouping at PCMI. He contrasted random grouping with purposeful grouping, which was introduced to him a few years before and made sense to him. However, Ezio then narrated how random grouping became a resource for him to experiment with. He continued by connecting his experience to the local school context and to an institutional practice he saw as inequitable (tracking):

Ezio:	I know where my bias is but—
Patty:	Yeah.

Ezio: Let's try it out. and I do— one thing I do fear... (1.5-second pause) so like what's bothering me in this school, we do— ok unofficially, unofficially we track kids.
Patty: Yeah.
Veronica: Officially.
Ezio: No, unofficially.
Patty: Yeah, well, we talked about this, right? last time.
Ezio: so I've had kids tell me, "Oh, we're in the dumb class." They know; they already have that label.
Lani: Is this one of the groups of kids that is in the "dumb class"?
Ezio: No, no.
Veronica: No.
Lani: Okay.
Veronica: ...like in a Kagan, when you purposefully group, the kids automatically know.
Lani: Yeah.
Patty: Yeah, which they do.
Veronica: Whereas if you randomly group, they don't know.
Lani: Right.
Ezio: Right, so I don't want to subconsciously be telling kids, "Oh, I think you're awesome."
Patty: Yeah, yeah.
Ezio: That's the one thing I did like about the random grouping.

Ezio contrasted random and purposeful grouping twice: First, when introduced to them; while he did not agree with random grouping, purposeful grouping made sense to him. Second, when evaluating their contribution to his sense of pedagogical responsibility; even though purposeful grouping made sense to him, it functioned to reproduce what was "bothering in this school." In contrast, even though he did not agree with random grouping for its lack of structure, the one thing that he did like about it was that it disrupted the institutional process of labeling kids.

Representation and framing. An aspect of teaching that becomes visible in Ezio's representation of teaching is that teachers are constantly exposed to many different, sometimes even contrasting instructional practices that they need to compare, contrast, and reason about. This representation, supported by the reference of the two external conceptual resources of random and purposeful grouping, afforded a framing of the problem of labeling kids that (1) underscores the local school context as Ezio experiencing it; and (2) positions the teachers as having "the power, authority and responsibility to cope with the problem" (Vedder-Weiss et al., 2018).

Pedagogical judgment. Ezio used the story of his engagement with random grouping, first at PCMI and then in the ongoing work of teaching, to reason about his pedagogical actions, and to stress their connection to his sense of responsibility to disrupt what he saw as unethical tracking in Rees Middle School. Specifically, random grouping could ensure that students did not perceive themselves to be "lower" or "higher" than others with regard to mathematical placement or ability. Puncturing the conversation at multiple points, random and purposeful grouping served as resources to support Ezio and Veronica's reasoning about their instruction. Ezio described himself as a reluctant user of random grouping while carefully articulating the reasons to use the practice. By doing that, Ezio made visible pedagogical judgments as an ongoing aspect of his practice, and the team consolidated connections between their actions and their shared sense of responsibility.

Discussion

We presented cases of mathematics teachers collectively reconciling local contexts and external resources. Teachers are exposed to many different, sometimes even contrasting, conceptions of good teaching (Britzman, 2012) in their larger learning ecologies, and external resources often aid in their sensemaking with and about these conceptions. By attending to these external resources, we

underscore a unique role of collaborative sensemaking opportunities in the overall teacher learning ecologies. Specifically, we build on previous situated research of teacher conversations to offer a discursive mechanism by which external conceptual resources contribute to teachers' pedagogical judgment: by affording richer representational infrastructure and more productive problem frames, teachers were able to bring their pedagogical responsibility, actions, and reasoning into closer alignment.

As a field, we came to acknowledge the importance of what the PME-NA Conference theme describes as "manifestations across different cultures, places and contexts." We see this work on external conceptual resources as a step towards developing better ways to design, facilitate and analyze mathematics teacher learning across contexts.

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