ANALYZING TEACHER LEARNING IN A COMMUNITY OF PRACTICE CENTERED ON VIDEO CASES OF MATHEMATICS TEACHING

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Incorporating video case study of mathematics teaching into professional development (PD) can provide opportunities for teachers to develop new ways of seeing teaching and learning and inform efforts to enact new instructional practices. However, more research is needed to understand how such PD can foster sustained teacher learning about high-quality instruction and materials. In this paper, we share the evolution of our analytic method that aims to reveal how secondary mathematics teachers learn while collectively analyzing video of mathematics teaching. We found that conceptualizing this PD within a community of practice, along with applying analytic tools from frame analysis and professional noticing, helped us recognize and describe the process of teacher learning in this setting. We plan to apply our analytic method to our full dataset to better understand how teacher learning in this context is happening over time.

Keywords: Teacher Education - Inservice / Professional Development, Teacher Knowledge, Research Methods

Teaching is a dynamic endeavor for each teacher; no two learning environments are identical. Each classroom is shaped by teacher and student interactions, including teachers' interpretations of and responses to students' thinking and problem-solving strategies. Teachers' decision making during these interactions provide opportunities for students to develop as problem solvers and effect mathematical thinkers (Schoenfeld, 2017). As educators, we can learn from classroom interactions, personal reflections, and collaborations with others in order to improve our own practice. Analyzing video case studies of mathematics teaching "can help [teachers] develop new ways of seeing teaching and learning and support their efforts to enact new instructional practices" (van Es & Sherin, 2017, p. 1).

However, teachers' opportunities to systematically develop and share ideas about teaching are limited (Ball, Ben-Peretz, & Cohen, 2014). Professional development (PD) has been shown to be key in supporting instructional shifts that deepen students' learning opportunities (Desimone, 2009). In our research, we designed a model of video-based PD for our work within professional learning teams (PLTs) of secondary mathematics teachers, bringing teachers together to collaboratively investigate video of mathematics teaching. One important aspect of our PD model is that it is grounded in the Teaching for Robust Understanding framework (TRU; Schoenfeld, 2017). The TRU framework details dimensions of high-quality instruction that support deep mathematical learning opportunities for students. Our goal is to understand (a) how discussions and activities used in the PD support teacher learning, and (b) the extent of teacher learning about high-quality instruction and instructional materials that can be used within mathematics classrooms.

Submitted to the Theory and Research Methods strand of PME-NA, this proposal describes the analysis process for the NSF-funded project *Analyzing Instruction in Mathematics using the Teaching for Robust Understanding Framework* (project number 1908319), or AIM-TRU. The project team consists of a research group of practitioners and mathematics teacher educators analyzing PLTs' investigation of video cases. Through our analysis process, we aim to demonstrate how our PD model can foster sustained teacher learning about high-quality instruction that contributes to shared professional knowledge across a diversity of school settings. As we worked to understand the impact of our PD model on teacher learning, we drew from and expanded on a collection of complementary conceptual and analytic perspectives, including communities of practice, frame analysis, and professional noticing. Thus, the purpose of this proposal is to share our analytic method and illustrate how we have been using it to understand how teachers learn in a community of practice as they collectively analyze video case materials.

Conceptual and Analytic Perspectives

Our conceptual model relies on understanding learning within a community of practice (CoP; Wenger, 1998). To understand learning in a CoP, we incorporate analytic tools from frame analysis (Bannister, 2015) and apply constructs from professional noticing (Jacobs, Lamb, & Philipp, 2010). In this section we describe each of these frameworks to articulate our process of investigating teacher learning within professional learning teams.

Communities of Practice

Wenger (1998) claims that people learn through their participation in specific communities, called communities of practice (CoPs), consisting of people with whom they interact regularly. CoPs are defined as groups whose members (a) are mutually engaged in an activity, such as analysis of video case studies of mathematics teaching; (b) are connected by a joint enterprise, such as fostering sustained teacher learning about high-quality instruction; and (c) have a shared repertoire of communal resources, such as the TRU framework.

According to Wenger (1998), communities of practice negotiate meaning collectively. This negotiation of meaning is represented by changes in participation which are reified to give form to the meaning through the three dimensions of the CoP outlined above. For our analytic process, we utilize frame analysis to identify these reified changes in participation, which manifest themselves as participants engage with "evolving forms of mutual engagement," "understanding and tuning their enterprise," and "developing their repertoire, styles, and discourses" (Wenger, 1998, p. 95). We consider changes within these three processes as evidence of learning within a CoP.

Frame Analysis

Bannister (2015) linked community participation with tools from frame analysis (Benford & Snow, 2000; Snow & Benford, 1988), to examine how teachers' participation patterns evolve around a community defined problem of practice (PoP). By employing the tools from frame analysis, Bannister sought to understand development within a group of teachers within common planning time to capture teachers' reification patterns and give insights related to member participation. The tools from framing analysis consist of framing tasks (Snow & Benford, 1988): diagnostic framing ("identification of a PoP and the attribution of blame" (p. 200)), prognostic framing ("a proposed solution to the diagnosed PoP that specifies what needs to be done" (p. 199)), and motivational framing ("a call to arms or rationale for engaging in ameliorative or corrective action" (p. 199)).

Bannister (2015) delineated the connections between the key concepts from frame analysis and processes of participation and reification in a CoP (see Figure 1). For example, a group of high school mathematics teachers (a CoP) collaborate weekly (shared repertoire) on developing interventions for struggling students (joint enterprise). As the teachers identify a PoP and specify possible causes (diagnostic framing), and discuss possible solutions (prognostic framing) by interacting each other and sharing their ideas (participation), the framings reify the community's ideas about who the struggling students are and what can be done to help them. Changes in framings within a community help to reify the changes in participation occurring within a CoP. These changes in participation and reification, are in turn, empirical evidence of learning occurring within a CoP.

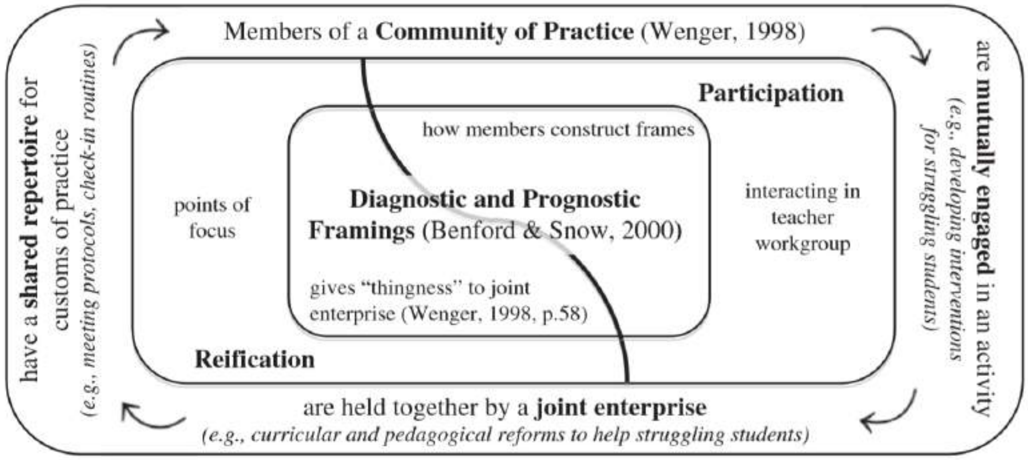

Figure 1: Connections between key ideas from communities of practice and frame analysis. (Bannister, 2015)

Professional Noticing of Children's Mathematical Thinking

To identify a PoP, we use the construct *professional noticing of children's mathematical thinking* to "begin to unpack in-the-moment decision making" (Jacobs et al., 2010, p. 173). Researchers argue that teachers need to first learn to productively attend to pertinent features of an instructional setting and be able to make mention of that which is noticed before they can make responsive instructional decisions (Jacobs et al., 2010; Superfine, Amador, & Bragelman, 2019). Thus, Jacobs et al. (2010) detail the components of professional noticing with three skills: "attending to children's strategies, interpreting children's understandings, and deciding how to respond on the basis of children's understandings" (p. 172). The premise of the framework indicates that in order for teachers to respond to student thinking, the other skills of attending and interpreting are occurring simultaneously to provide the teacher insight and knowledge about how to respond. Moreover, according to Thomas et al. (2015), anticipating how students might respond provides a firm basis of noticing. Therefore, the framework for professional noticing for children's mathematical thinking provides a foundation for us to apply frame analysis techniques to understand the ways in which teachers are learning within a CoP.

Methods

Participants

The participants of the study include eight practicing secondary mathematics teachers and two participant observers from the research team. The teachers volunteered to be part of a Professional Learning Team (PLT) with the goal of analyzing videos of mathematics classrooms to interrogate mathematics teaching and learning. Two of the eight participants are facilitators for the discussions; however, the two research members also engage and probe teacher thinking throughout the PLT meetings.

Context

Teacher participants who elected to participate in this PLT enrolled with the knowledge that they would be analyzing video case studies that are aligned with the TRU framework. Each set of video case materials utilized in PLT meetings was created to demonstrate a teacher implementing a formative assessment lesson (FAL) from the Mathematics Assessment Project. The Mathematics Assessment Project also uses the TRU framework as a way of characterizing powerful mathematics classrooms, defined by a focus on the mathematics, cognitive demand, equitable access to the mathematics, agency, ownership, & identity, and formative assessment (Schoenfeld, 2017). The TRU framework provides a necessary shared repertoire within the PLT for discussing the video case studies.

Participants attended four PLT meetings and analyzed three sets of video case materials. The first PLT session was used for teachers to better acquaint themselves with FALs and the TRU framework with the intent to build a shared repertoire among members. In the next three sessions the participants engaged in a guided analysis of video case materials. Each PLT meeting was two hours in length. The teachers engaged with mathematical content around applying properties of exponents and representing quadratic functions graphically. The facilitators followed a predetermined guide to keep each session consistent throughout the larger project.

Data Collection

Data was collected with the intent of understanding how teachers develop knowledge through engagement with the video case materials. The four PLT meetings were video recorded and each of the recordings were later transcribed to be analyzed. Materials from the PLTs were also collected to cross reference teacher conversation and build knowledge of their understanding. The materials include individual and group generated artifacts, solutions, and responses to question prompts.

Data Analysis

In order for us to understand changes in participation and reification within the CoP, we used frame analysis (Bannister, 2015) as an analytic tool. Our first level of analysis was to reduce the data into episodes of pedagogical reasoning (EPRs). Horn (2005) defines episodes of pedagogical reasoning as

> units of teacher-to-teacher talk where teachers exhibit their reasoning about an issue in their practice. …EPRs are moments in teachers' interaction where they describe issues in or raise questions about teaching practice that are accompanied by some elaboration of reasons, explanations, or justifications. These episodes can be individual, single-turn utterances, such as "I'm not using that worksheet because it bores the kids." Alternatively, these can be multiparty coconstructions over many turns of talk. (p. 215)

Using an EPR as our unit of analysis, we were able to systematically investigate teacher discussions. After collectively identifying each EPR, we analyzed the EPRs to determine what teachers were talking about and the nature by which they were having discussions.

After separating EPRs, we created descriptions or themes to characterize the essence of the conversation. These descriptions detail what the teachers were discussing. For example, two of our identified themes were *understanding one method of student strategies* and *using calculators to evaluate vs. expanding*. To apply frame analysis, we examined each EPR and the previously identified theme to determine the PoP which grounded the teachers' conversations. The PoP occurred when teachers identified an instance as troublesome, challenging, recurrent, unexpectedly interesting, or otherwise worthy of comment (Horn & Little, 2010); they are issues of practice that teachers encounter regularly. We identified the PoP through either explicit mentioning from participants or through prior participation or discussion. While we were stating the PoP in each EPR, we began to discover repetitive language emerging as we defined the PoPs. Therefore, we began to create descriptions of PoPs that could be used across the PoPs and revisited each previously analyzed EPRs to determine if they would also have our newly defined PoP. For example, we analyzed the two EPRs with different themes, labeled above, and determined that in both cases the PoP was *teachers anticipating student solution strategies.*

After identifying the PoP, we analyzed each EPR to understand the nature of the conversation through frame analysis. Incorporating the literature, we organized the definitions of framing tasks as detailed in Table 1.

Table 1: Definitions of Framing Tasks

Framing Task	Definition
Diagnostic Framing	Diagnostic framing is when teachers diagnose a PoP and attribute causality for the problem.
Prognostic Framing	Prognostic framing is when teachers discuss a solution or possible solutions for a PoP diagnosed or implicit from earlier conversations. This implies attribution of causality and solution(s) for the problem.
Motivational Framing	The motivational framing is the rationale for engaging in a particular action to attend to a particular PoP. This rationale should be more than just mentioning what the teacher thinks will change but include justification for why the proposed action will create change. This implies attribution of causality, solution(s) for the problem, and a rationale for why a solution or solutions would actually work.

We described the diagnosis, the prognosis, and/or the motivation with each EPR. The descriptions were generated by using the teachers' exact words or by interpreting the nature of the teachers' conversation. In some EPRs, we saw a progression of conversation from diagnosing the PoP, to prognosing a hypothetical solution, to detailing their motivation behind their prognosis. However, other EPRs were limited to only diagnostic discussions where the teachers did not provide hypothetical solutions to their identified PoP.

During the analysis process, we began to see patterns in our identified PoP and considered layering frame analysis with an additional analytic framework that would help us better understand what the teachers were talking about before we determined how they were talking about it. Through discussions, we realized that the PoPs contained themes aligned to the professional noticing of children's mathematical thinking framework. As a team we revisited the definition of each PoP to align them with the framework as an object of focus for the community's participation and reification. Figure 2 indicates how we visualize the noticing framework inside of a CoP. What and how the teachers notice throughout their engagement with video case studies can be evidence of changes in participation and reification.

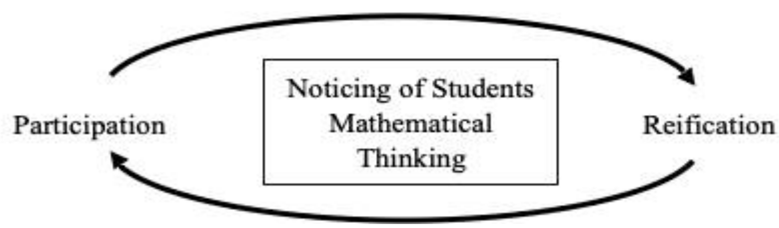

Figure 2: Noticing as a method to analyze changes in participation and reification.

Based on the professional noticing framework, to define our PoP, we categorized each EPRs' problem of practice as either attending, interpreting, or responding to student thinking. In our analysis, we also detailed the subject to what the teachers were either attending, interpreting, or responding. For example, the two EPRs, identified earlier regarding student solution strategies, were now coded as *Attending-Teachers anticipating student solution strategies*. However, using the definitions for attending, interpreting, and responding, we found some EPRs could not be characterized by one of these categories. In these instances, the teachers were not explicitly discussing students' mathematical thinking. However, because the context of their conversations is important for our larger research project, we categorized these as "other" and maintained the original description as the PoP.

Illustrative Example of our Analytic Method

In this section, we provide an illustrative example of our analytic method. We detail the processes of identifying an EPR and the PoP within the EPR, relating the PoP to the noticing framework, and identifying each EPR as a diagnostic, prognostic, and/or motivational frame.

For context, the participating teachers in this example were analyzing the video case of an Applying the Properties of Exponents FAL during the second PLT session (https://tle.soe.umich.edu/MFA/Applying_Properties_of_Exponents_1). While analyzing the video case, the teachers focused on a group of students discussing the problem $2^2 \div 2^3$. Two of the students in the group were trying to convince a third student how the properties of exponents could be used to simplify this expression. The following transcript is a teacher conversation in the PLT meeting about the situation in the FAL.

Louis: I think if I could rewind then ask a question, I might ask them or maybe prompt them to do is maybe to think about it in terms of a different form. Because, from what I saw, it was like a back and forth between computation and exponents. And I think if maybe the students could maybe see it in the expanded form or another way it might, it might prompt them to think about it in a different way.

Josh: Can I ask how you would go about doing that? Like, what would you ask them to stimulate that conversation?

Louis: I think I would start at the beginning and I think it was where they were doing the four divided by eight … it was two to the second divided by two to the third. That's what it was. And that prompted them to do four divided by eight. And they got some, they got some validation at the end, like he checked into the calculator and yes, in fact it was two to the negative one power. So, I guess the question would be like, well why exactly does that work? And then it would be, what's another way maybe we could write the initial statement and then maybe that would help them along the way to the other ones.

Jackson: I agree. Have them write it in expanded form and then playing with it that way.

Lisa: I know for me, one of the things I would have, um, and I again, I don't know if this is the right move, but being that it seems like the boy is a very visual person. Maybe he's not really listening to these rules because he's not getting, he's not really seeing their thinking. Uh, I know like I'm a very visual person. I need to see it written to really understand it. So, I almost want to suggest to the girls like, can you just show, show him what you're thinking? Can you show it on your whiteboards? And maybe then he'd have like a better understanding for it.

We identified this teacher conversation as an EPR because it was an incident of teacher-to-teacher talk about a student who had not been building on other students' thinking or reasoning about $2^2 \div 2^3$ and were offering suggestions for improvement. We identified the PoP in this EPR as *providing opportunities to learn in different ways through multiple representations*. Evidence to support this description can be seen, in part, through one teacher's comment: "And then it would be, what's another way maybe we could write the initial statement and then maybe that would help them along the way to the other ones" (lines 13-14). Based on the professional noticing framework, we categorized the PoP as *responding to student thinking* because the teachers used what they learned about the student's understanding of the properties of exponents to pose hypothetical questions to students. As stated earlier, for teachers to respond to student thinking, they must first attend to student thinking. Evidence of teachers attending to student thinking occurs when Louis claims that he saw students using computation and expanding as methods of simplifying exponential functions (lines 2-4). We identified other hypothetical responses to student thinking by the teachers: Louis proposed probing student thinking by asking why their mathematics works (lines 12-14); Jackson suggests having students write the expressions in expanded form (line 15); and Lisa would ask students to make their thinking visible through the use of whiteboards (lines 20-22). In each of these instances, the teachers are sharing questions they would ask students in response to the analysis of their thinking.

We then analyzed the EPR to understand the nature of the conversation through frame analysis. The teachers diagnosed the PoP as *responding to student thinking: providing opportunities to learn in different ways through multiple representations*. They came to this diagnosis by focusing on one student who did not believe that one representation (the properties of exponents) was valid to illustrate the equivalence of expressions. The teachers' determination of the attribution for causality, or what caused the PoP in this EPR, was that the student did not build on other students' thinking. This is evidenced in Lisa's claim, "Maybe he's not really listening to these rules because he's not getting, he's not really *seeing* their thinking" (lines 17-19, emphasis added).

The teachers went on to provide a prognosis for this PoP. In this EPR, the teachers discussed prompting students to consider looking at the expanded form of $4 \div 8$ (line 9) written on the whiteboard (line 21) because it would be helpful for the student, who might be a visual learner, to see and understand the properties of exponents are valid to illustrate the equivalence of expressions. In the end, we coded this EPR as a motivational frame because the teachers went beyond the diagnosis and prognosis of the identified PoP by providing a rationale for their proposed action based on their assessment of the student appearing to be a visual learner (lines 17-22). The summary of our analysis for this illustrative example is organized and presented in Table 2.

Table 2: Sample Analysis

Category	Description
Problem of Practice	Providing opportunities to learn in different ways through multiple representations
Noticing Skill	Responding to student thinking
Diagnostic Framing	The student doesn't believe that one representation (properties of exponents) is valid.
Prognostic Framing	The teacher could prompt students to consider looking at the expanded form of expressions.
Motivational Framing	The student appears to be a visual learner, thus seeing expanded form might assist his belief in properties of exponents.

Discussion

Our analytic method stems from a need to understand how teachers learn in a CoP and, in turn, how to foster sustained teacher learning. In this paper, we elaborated how our analytic method is helpful to understand teacher learning within the PLT during their engagement with video cases. First, frame analysis enabled us to analyze what and how the teachers negotiated meaning in the PLT. Meanwhile, we saw that, during the teachers' interaction, they mostly talked about noticing their students' thinking. Thus, by adding the noticing framework to frame analysis, our team was able to categorize the PoPs in a consistent way. This consistent categorization of PoPs was beneficial to understand how the teachers could start to think about improving their own instruction. Taken together, within our analytic method, we combined frame analysis and professional noticing, which was conducive to our analysis of teacher conversations about FALs. Specifically, frame analysis played a major role while the noticing framework played a supporting role in our analysis process because we utilized the noticing framework after making use of frame analysis. If researchers or teacher educators apply the analytic method in their own context, it might be helpful to utilize an additional framework, like professional noticing, from the beginning of an analysis. By characterizing the PoP in a streamlined manner, patterns related to participation and reification will become more easily evident through analysis. Then, through analysis of the entire PLT data, using the identified PoPs, we will be able to discern if there are reified changes in participation.

Next Steps

In order to better understand teacher learning within PLTs of practitioners and mathematics teacher educators analyzing video cases, we first need to further investigate how teacher conversations and their framings are changing over time. These changes in frame will allow us to identify and describe the reified changes in participation that indicate learning in CoPs. Secondly, we need to look for patterns across EPRs in the remaining sessions of the PLT to verify that this analytic method is robust. Additionally, it will be necessary to determine how to interpret the EPRs we categorized as "other." Our initial understanding of this collection of EPRs is that they are about group dynamics or classroom norms. However, we will need to continue to look at this data, and the PLT sessions to find confirming or disconfirming evidence of this conjecture. Finally, future studies can build on our analytic method by connecting this data to the TRU framework in order to obtain a deeper understanding of our overall research questions around understanding (a) how discussions and activities support teacher learning and (b) the extent of teacher learning about high-quality instruction and instructional materials that can be used within mathematics classrooms.

Acknowledgments

This material is based upon work supported by the National Science Foundation under grant number 1908319.

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