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Professional Development in a Laboratory Setting Examining Evolution in Teachers' Questioning and Participation

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This paper reports on an analysis of teachers' participation in the observation and collective examination of a laboratory class in which an experienced elementary teacher taught 30 rising fifth graders all morning every day for two weeks. The study on which the paper is based, called a laboratory class, probed how a group of practicing teachers participated in co-planning, watching, and discussing this mathematics class as an opportunity to engage in collective study of practice. This unusual context offers a site for investigating a particular form of practice-based professional learning. Analysis of teachers' discussion guided by the kinds of questions teachers asked and characteristics of their participation in the collaborative investigation of the practice, indicate a shift in teachers' noticing, from pointing students' errors to unpacking mathematical thinking behind it with more engagement in providing concrete suggestions and mathematical representations that are customized for specific students' misconceptions. Moreover, the analytical framework used in this study, brings forward characteristics for teachers participation in a professional development setting.

Key words: Laboratory setting, professional development, teacher noticing, teacher participation, teacher questioning

The recent emphasis on practice-based professional development (Ball & Cohen, 1999) has made popular the use of artifacts of practice in professional development. Many studies use videos of teaching as records of the practice. These studies claim that teachers learn significantly from reflections based on authentic representations of practice (Borko, 2004) and videos of teaching are one among such authentic representations. (Santagata, Zannoni, & Stigler, 2005). The use of videotapes for the study of teaching in professional development has become increasingly common. Although, a range of design principles guide these varied programs, a key assumption shared by many of them is that watching teaching and reflecting on it is thought to be a valuable activity for teachers, one that has the potential to foster teacher learning (Sherin & Han 2004) and one that opens up a window into classroom dynamics that conveys "the complexity and subtlety of classroom teaching as it occurs in real time" (Brophy, 2004, p. 287).

On the other hand, in an in-service professional development program watching live teaching to learn about teaching is much less common, mainly due to the logistical requirements. Although, the research is somewhat limited, observing live lessons have been shown to have the potential to enhance teachers' professional learning, mainly bringing changes in their beliefs and practices (Grierson & Gallagher, 2009; Saphier & West, 2010). Studies where professional development program involved tasks around actual teaching, teachers indicated that, "the modeling, observing, debriefing and problem solving were the most valuable components" (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004, p. 447). The engagement in actual teaching with their professional community leads to situated learning, as the learning context is the same in which it is applied (Greeno, 2003; Lave & Wenger, 2001).

The laboratory class is a unique example of a setting, where teachers are engaged directly with practice, not only through observing live teaching, but also co-planning it with the laboratory class teacher. Teachers' participation in the laboratory setting that involves co-planning the class, observing the enactment, and reflecting on the enactment in collaboration, proves to be authentic in teachers learning to notice mathematically and pedagogically significant phenomena in the classroom interaction and especially in students' responses.

The Study

The data presented in the paper come from one cycle of the laboratory class. To comprehend teachers' participation in the (live teaching based) professional development, the discussion after the actual enactment was analyzed. This discussion was guided by the questions, comments and suggestions from the teachers, which they asked to the laboratory teacher, who taught the 5^{th} graders. Therefore, the nature and shift in teachers' participation is observed through what teachers asked, suggested or noticed.

1. What kinds of questions did teachers ask during discussions about the teaching in the laboratory class that they co-planned, observed in a live setting?
2. What are the characteristics of teachers' participation in a collaborative setting such as the laboratory class and how did this change over the time?

Design of the Laboratory Class

The laboratory is a setting for special mathematics class for entering fifth-graders, many of whom have not experienced success with maths in school. The learning opportunities for teachers were organized in three events: (1) a pre-briefing, (2) class observation, and (3) a de-briefing.

Pre-briefing and the lesson plans. The pre-briefing sessions happened before the actual enactment of the lesson. During these sessions the laboratory teacher, who taught the 5th graders, presented the day's lesson plan, explained the goal and activities for the class, and discussed any concerns that she or other teacher-cum-co-planners had about the lesson or particular students in the class. The lesson plans prepared for teaching were more detailed than typical, mainly to exhibit "public teaching" (Ball, 2014), that enabled more visibility of teaching. This was achieved by adding sections that displayed teachers thought processes, preparation and considerations to make best use of the teaching events and students' responses. The plan included a list of mathematical practices utilized in teaching; a list of teaching practices that the teacher will be engaged in and also a set of learning practices that students will be encouraged to exercise.

Class enactment and observation. The laboratory teacher taught the class and other participant teachers observed the enactment. During the two and a half hour instructional period, observers were seated on risers in the back of the laboratory classroom. Students are made aware of these participant observers; similarly participant observers sign and follow consent, not to disturb the teaching practice.

De-briefing and planning for the next day. After students leave the classroom, the participant teachers are invited to study the students' work in their notebooks and on the whiteboards. The analysis of the enacted classroom, suggestions or planning for the next day's teaching with other clarifying discussions took place in the de-brief session. The participant teachers spoke most in this session compared to the pre-brief. The discussion consisted of questions, mainly posed to the laboratory teacher about that day's teaching, some suggestions and clarifications.

Participant teachers in the laboratory class. A total of 31 teacher participated in the laboratory class. Most of them were mathematics teachers teaching to grades 3^{rd}, 4^{th}, 5^{th} or 6^{th} in different states of the USA; one of the teachers was going to teach mathematics for the first time; there were two mathematics educators from the outside of USA; two of them were instructional facilitators; two retired teachers now working as instructors in teacher education; and four teachers in the group had students from their own classroom in the laboratory class.

Analytical Framework

The research questions are answered through two-filtered analysis of teachers' questioning. The first filter was to see what categories are present in the questions that teachers asked, and the second to understand what characteristics of participation these questions exhibit and how those associate with the design of the laboratory class.

Analyzing Evolution in Teachers' Questioning

In the transcription of the teachers discussion during the de-brief, the questions asked by the teachers, yielded three categories of focus: (1) what to tell or not tell your students (these questions often focused on students perceived errors and misconceptions); (2) material use and ways it might be adjusted or modified; and (3) students' engagement in the classroom. A *qualifier tag* (Kazemi & Franke, 2009) was attached to each question, indicating whether the question is – centered around the teaching practices; about the knowledge belief of the laboratory class teacher; suggesting changes in content or pedagogy; or reflecting on similar events from the teachers own classrooms. A discrepancy was noted when teachers' personal views of teaching a particular topic was conflicted with what was practiced in the laboratory class. For example, on day 1, when teacher began with a task that needed knowledge of fractions, one of the teachers raised a concern, as "why 'numerator', 'denominator' kind of language was not introduced first?", indicating a presumed trajectory for teaching fractions. The result section narrates an evolution in teachers' questioning over the period of the laboratory class.

Analyzing Teachers' Participation in the Collaborative Investigation

Lave and Wenger (1991) argue that learning occurs as one participates in the community of practice through a process called Legitimate Peripheral Participation (LPP). LPP is not a teaching technique but an analytical viewpoint on learning, a way of understanding learning, and therefore used for designing learning opportunities, and individual's role in that opportunity. "Viewing learning as a legitimate peripheral participation means that learning is not merely a condition for membership, but is an itself an evolving form of membership" (p. 53), emphasizes individual's participation in a community of practice and shift in it, as an indication of learning from the community.

Building on Lave and Wenger we identified characteristics of teachers' participation (Naik & Ball, 2012) that impacted the issues teachers raised and considered central to the practice. Table 1 summarizes the characteristics that are studied for teachers' participation and in the results section we discuss each of the characteristic.

Table 1
Characteristics of Teachers' Participation in the Discussion Around the Live Teaching Observed

Participation characteristics	Meaning and codes generated
Positioning	Indicates how teachers referred to themselves and others during the conversations (participant teacher, co-planner, a mathematics teacher, etc.)
Proposing improvements in teaching	Passive or active. Passive is where they gave advice in general (e.g., actual visuals of the fractions would be useful) and active is when they had actual enactment in their mind (describing the complete making and use of activity or teaching aid)
Pedagogical content knowledge	References to representations, examples and students' mathematical thinking.

Results and Discussion

Evolution in Teachers' Questioning

The challenges or discrepancies and suggestions that teachers raised during the discussion are reported in the four main categories. Table 2 provides number of questions in each category over the period of 6 days in the laboratory class. Students' misconceptions were the focus of discussions from the beginning. The students' errors were seen as a failure of the instructional process than as a window to students' thinking. On the first day during the discussion, the focus was on, how lack of "clear answers", "clear instruction" or "knowledge of mathematics procedures" could lead to errors in students' work, where as towards the end of the laboratory class, the focus was more on unpacking the students' reasoning and responses, irrespective of whether it led to right or wrong answers.

The four categories mentioned in the Table 2 are not exhaustive of the questions that teachers asked but are the prominent ones observed on day 1 and 2. The focus of discussion became more personalized as the laboratory class progressed. For example, some teachers focused on a particular student, and started discussing what that student said in the class, what is she writing in the notebook, what she might have thought, etc.; whereas other teachers followed use of notebooks by the laboratory class teacher and discussed how they used notebooks in their class.

Table 2

Categories in Teachers' Questioning

Days	Students' misconception		Material use and modification		Classroom management		Students' maths thinking		Question Qualifier
Day1	6	28%	5	24%	10	48%	0	0%	Challenge
Day2	4	22%	8	45%	4	22%	2	11%	Challenge/ Suggest
Day3	4	19%	7	33%	0	0	10	48%	Suggest
Day4	5	20%	8	32%	0	0	12	48%	Suggest/ reflect
Day5	7	33%	1	5%	1	5%	12	57%	Reflect/ Suggest

The qualifiers (Table 2), challenge, suggest or reflect were decided on the basis of teachers' emphasis in questioning – a challenge was considered when teachers suggested an alternative emphasis or showed disagreement to the laboratory class teacher's action, mainly of delaying in providing the correct answers. For example, on day 1 there was a problem posed for the students to name fraction for a shaded part where, rectangle was unequally divided (See Figure 1). Students came up with three answers for the problem – 1/3, ¼ and 1 ½. For each response, the laboratory class teacher made other students ask questions to the students who came up with the responses, to understand how the answers were obtained. The student with answer 1 and ½ justified that the big rectangle in the figure is a whole and therefore the non-shaded portion of the figure is 1 and ½. After her explanation to the whole class, in the next round of naming fractions task, most students followed her approach and took the liberty in deciding the whole on their own and then finding a name for the shaded part. It was apparent that students were influenced by the strategy of choosing the whole on their own and however they all were mathematically correct, they were arriving at different names for the same shaded portion, depending on their choice of the whole.

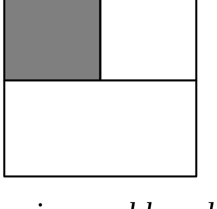

Figure 1. *Fractions naming problem discussed in the class.*

During the de-brief of this class, teachers challenged promotion of the idea of choosing different wholes, mainly because it will lead to different answers. Comment 1 in the Table 3 is an example where students' misconception is focused than the mathematical thinking behind it. In this comment, the reference to student's method as a *wrong method* is an indication, that idea of flexible wholes is taken as a challenge in teaching "for a correct answer" rather as an opportunity to develop students' mathematical thinking. Naming of fractions is dependent on the size of the whole, and therefore idea of flexible wholes is not only exercising what fraction means, but it also unpacks a critical component of the process of naming fractions – i.e. deciding the whole. When asked by the laboratory class teacher whether it is really wrong, there were few turns of the discussion among teachers. And here (Comment 2 in Table 3) is what another teacher responded, where the concern is how to bring all the students on one page – mainly to get the same answer.

Table 3
Teachers' Responses on Students' Reasoning: "A Wrong Method"

1	"I loved when you were getting their guesses, their educated guesses about what the second picture, where it was divided into three unequal parts, you listed their three guesses and one child had 1/3rd, one with 1/4th and other came up with 1 and a half. And she was the only one admitted publicly that getting that answer and no one else admitted that and there is little bit of discussion of how she got that and which I kept thinking that wow she is great, well when we looked at the journals what happened is several of the students convinced themselves that her method is the right method instead of a wrong method."
2	"Well, it is not wrong but again I keep going back to my thought that wow it is genius, you put it so eloquently that she pursued the whole and that's how she got one and a half, but my question is… my observation is now what we do tomorrow, with all of these other kids, who have convinced themselves, that that is how we come up with answer?"
3	"One thing I noticed with Alison, at the beginning of the week I saw explanations being not that good, like "because I got the right answer", but I am starting to see that she is been able to articulate a little bit clear and why she did what she did. Not just saying that she got the right answer but she might say something like, both sides are equal or she will be more specific, if this side is 5 then the other side needs to be 3 for number 15. So I think their explanations for majority have gotten clearer. I will probably still focus on that in their notebooks…"

The major chunk of the discussion was taken up by these questions, whether the method of choosing wholes to name fractions is wrong in itself and what should we tell students in order to teach them naming of fractions. The reason that teachers challenged the laboratory class teachers' decision to discuss an atypical response in the classroom is because of the heavy emphasis on students' performance on the tests, where often questions with one specific answer are asked. However, in the laboratory classroom, repeated exposure to students' thinking, their alternate ways of doing mathematics, made teachers realize that focusing only on the answers does not provide insight into students' mathematical work. On day 3, one of the participant teachers is reflecting on a student's oral explanations and hinting (Comment 3 in Table 3) that similar needs to be worked out for their written work. These and similar responses, indicated a shift in what teachers began to notice – mainly from focusing on getting a right answer, to be able to explain why that answer is right. The laboratory class teacher's emphasis on exploring students' thinking might have led to this awareness among the teachers.

There were many events of talk where the discussion began with a challenge, but resolved with a suggestion, more often in the later days (See Table 2). The laboratory created a complex space for continuous reflection, letting teachers to co-plan the teaching, watch the teaching with a lens of their personal experiences and a detailed lesson plan, and finally collaboratively investigating the teaching for students' learning, This reflection not only changed the kinds of questions teachers asked but also what events from the class they found significant to discuss.

Characteristics of Teachers' Participation

Characteristics of the teacher talk that their participation are listed and defined in Table 1. The following paragraphs provide description of those characteristics of the teachers' participation in the laboratory class, namely, positioning, proposing improvements in teaching and pedagogic content knowledge.

Positioning. Teachers positioned themselves in multiple identities during the de and pre-brief discussions. Their self-positioning was accessed through how they referred themselves with respect to the laboratory class teacher and other teachers.

The first comment in the Table 4 was given when there was a discussion about students' work on naming an unequally partitioned fraction. This comment is not just an acknowledgment of the problem but a suggestion to support for what can be done. This teacher's sense of identity as a co-planner is leading to the reference as "we". Including the laboratory class teacher as part of the group of participant teachers in their reference began to happen from day 2. Day2 was the first time teachers' suggestions were concretely present in the lesson plan that was enacted. Some responses from day 1 given in the Table 3 showed a different *positioning* than what we saw in the discussion from day 2 onwards.

Although the transition from "I" and "you" to "we" sounds trivial, it did happen, strikingly from day 2 onwards. Then on, "we" took responsibility of every action that happened in the laboratory class classroom. The few references to "I"s came when the teachers wanted to describe something that they did in their own teaching and again on the last day, during a discussion on what they take from the laboratory class to their own classrooms. The referencing to oneself as "we" did impact teachers' engagement, especially in terms of the improvements they suggested.

Table 4
Teachers' Positioning In the Laboratory Class

(Day 2, in de-brief)	"Some students have problems with just visual representations, they need association with verbal explanation or at least with some terminology. So if *we* tell them to say how many equal parts every time they write fraction for shaded parts, will help them."
(Day 3, in de-brief)	"I think *we* need to offer something that will pull some of these things out, to make them more clear. Offer some of the terms so *we* can use shaded—un-shaded and so on some other unequal parts. That is what *we* need."
(Day 1, in de-brief)	"…I thought at one point specially when they said, when *you* were trying to talk about the differences between the two shapes they were looking at to specify the equal parts. Just because from... they took the assessment in this spring I knew... at least the students I worked with had a difficult time for the visual representation of the fractions. And so...That is mainly why *I* would have probably, if it would have been the teacher, *I* would have done that language part today"
(Day 1, in de-brief)	"As you were doing the number problems, to the sentences, ten was always on the right. Do you think of flapping that tomorrow or in the future so that kids don't always get locked into that? I think *you* should try that…"

Proposing improvements in teaching. From day 2 onwards, teachers provided suggestions in teaching that were more detailed, and with considerations of its enactment in the class. Every day the suggestions teachers gave were discussed and weighed to understand its relevance and use in students' learning in the laboratory class. These suggestions then were actually used by the laboratory class teacher, which brought a greater authenticity to their suggestions. This whole process impacted suggestions for planning, which over the time became concrete day by day.

> "For teaching equivalent fractions, I tried the activity of superimposing cut-outs with my kids. We can take transparent sheets and make fractions on them. Colour the parts, as you will do on a normal paper. For example, 2/6 and 1/3, you make a cut-out for 2/6 by shading 2 parts out of 6 and then make cut-out of 1/3 by shading 1 part of 3…the whole has to be exactly the same while making the cut-outs. We can use different kinds of shading as later when we superimpose it will be visible, distinguishable… they understand why those fractions are equal" (Day 3, in de-brief)

The actual quote is very long and the details provided for the suggestion of teaching equivalent fractions are much finer. These suggestions are very different than what we hear in any traditional professional development workshops, where teachers would often say, "making visuals is good for teaching equivalent fractions" or "I use the transparent cut-outs for teaching fractions".

As mentioned earlier, design of the laboratory class, created a complex space for teachers to learn, where often they learn through what they are noticing—questioning—suggesting. Site such as the laboratory class, allow duality of perspectives (Naik & Ball, 2012) – one, where teachers constantly refer to their own identity as practicing teachers and second, as a co-planner of the collaborative planning and investigation of the teaching. During these five days, the teachers pursued their own interests, their own challenges. And above all, even though the teachers were part of the work of teaching, the accountability of actual teaching was not on their individual shoulder. Therefore, along with the duality, there was a space for individual autonomy.

Table 5
Teachers' Planning Together In the Laboratory Class

- Charts are around the room with the rectangles from 1 – 36. Provide Grid Rectangle Table synthesizing the information about the rectangles: number, factors, # of grid rectangles. Leave a few of the rectangles blank in order to give students a chance to better understand what information is included in the chart and from where it comes.Compare Grid Rectangle Table to the posters hanging around the room. Work together as a class to discuss and fill in missing information. Numbers left unfilled: 10–4 factors from an even number 16–Square number (odd number of factors-5) 18–composite 6 factors 27–4 factors from an odd number 29–only 2 factors?? - Look for other numbers that fit in these categories? Other patterns you notice?	*Possibilities:* 1. Numbers that have only 2 grid rectangles are prime numbers, $1 \times p$, $p \times 1$ 2. The number 1 has only one rectangle 3. If N gets bigger, that does not mean that the number of rectangles gets bigger. 4. Numbers that <u>have an odd number</u> of grid rectangles are squares because one factor pair ($n \times n$) cannot be rotated to create a complementary fact 5. There are <u>3</u> rectangles exactly when N is the square of a prime number. 6. Numbers having 3 or more factors are all considered composite numbers. Look for patterns of numbers that have a common number of factors. 7. There are four rectangles exactly when <u>either</u> N is a product of two different primes, <u>or</u> if N is the cube of a prime (like $8 = 2^3 = 2 \times 2 \times 2$, or $27 = 3^3$). 8. The number of rectangles depends only on how many primes occur and how many times each of those primes occur, but <u>not</u> on what the primes are.

Pedagogical content knowledge. The more attention towards students' thinking, kinds of representations, elaborations on what to teach next day and substantial discussion on how to deal with students' mathematical ideas, demonstrated teachers' pedagogical content knowledge around mathematical topics such as fractions, equality, number-sense in the pre and debrief sessions. The discussion around the topics was always situated either in the laboratory-teaching context or in the context of their own teaching. Often parallels were brought from what they do *usually* and what they *see* now and how they plan to change.

Table 5 is a section of the lesson plan from day 5 – displaying teachers' collective knowledge of possibilities for mathematical discussion in the classroom on the grid rectangle activity. The fourth possibility in the right column (Table 5) prepared the laboratory class teacher to build on students' observation for number of factor pairs, and if they are odd, then one of the pairs is making a square and therefore the rotation won't produce a new dimension for length and breadth. The geometrical representation of square numbers or operational understanding of prime numbers, made the classroom not only interesting but also mathematically dense. Teachers' recognition that mathematical preparedness of such kind and lack of exposure to be able to do that, confirms a call for specialized content knowledge (Ball, 1999; 2008) needs for teaching mathematics.

> "I also have a second point about what I gained from this week… is again I think I have said this several times… from just one lesson, the grids, the rectangular grids, the amount that we taught… just for that problem, even today prime numbers and square roots, that's to me, that is so powerful, and I think…I was talking to Eddie about this that it wasn't so much about that they will remember it, but they will able to recall it and make associations better when this is brought to their attention again." (Day 5, in de-brief)

> "…the square roots, and having the kids see the squares, it kind of lead to the conclusions on their own, just brought me back to even when I was in school, okay, I learned what a square root was, but I never had a visual of having to make a square, I didn't have that. That would have helped so much. Meaning wise it gives so much to think about…I wonder we need to work together for other such concepts…" (Day 5, participant teacher in the laboratory class-de-brief)

Again here there is a hint in the quote that teachers need settings where they all "need to work together for other such concepts" – that values the existing setting being fruitful and realization of requirement of such knowledge produced in such settings. The reason the space provides in the laboratory is different, because one can list all the possible representations and provide those to teachers, but they won't be any effective unless the teachers see them in actual practice.

Conclusion

Achieving change in teachers' participation, so that teachers become sensitive to those classroom events, that are significant in unpacking students' thinking and identifying representations, mathematical preparations needed to teach, is an important goal of any teacher professional development. This paper narrated a complex space for such learning where not only teachers are participating as professionals, but also investigating the practice as researchers. The paper proposes two things, one, that teachers' questioning is a productive lens to analyze the shift in what teachers' notice in and around the practice and second, the existing professional development programs need to design sites such as the laboratory class to create complex learning spaces for our teachers. Each practicing teacher, could review teaching from a teacher perspective, from the perspective of co-planner and collaboratively. This multi-identity facilitating space in the laboratory empowered teachers to study the teaching with more authenticity and depth. However, the study raises some fundamental questions such as, how can we use the school settings which almost has the equivalent complexity, for teachers' own professional development, what role peer teachers can play in eliciting pedagogic and specialized content knowledge and what measures are needed to encourage our teachers, so that they open their teaching for similar collaborative studies. Also what kinds of resources teachers produce that would be useful for the peer teachers. The question of resource is of particularly importance as what would be produced will be contributing to the teachers' pedagogic content knowledge, and has emerged from their collaborative specialized content knowledge.

Author Note:

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