



# Tracing Teacher Learning through Shifts in Discourses: The Case of a Mathematics Teacher

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## ABSTRACT

This study presents a methodology for investigating teacher learning in and from practice based on *discourses* that are in constant flux and transformation. Conceptualizing teacher learning as a frame of meaning based on *knowing* and *doing* discourses, the ideas are illustrated through data collected from a secondary mathematics teacher conducting an inquiry of self-practice. Narrative analysis of the data from the teacher interviews was conducted along with classroom observations of the teacher's mathematical practice. The data supported that tracing shifts in teacher discourses enables to understand the connection between the teacher's past discourses and the present discourses when identifying teacher learning. It is concluded that tracking teacher learning through two complementary discourses of the teacher's instructional practice enabled a unification of individual and collective levels of the teacher learning by self-inquiry of own practice. Moreover, through the continuum of discourses, this study provided insights about the generation of new meanings through transformation of old meanings in the teacher learning.

**Keywords:** discursive learning, learning in and from practice, teacher discourses, teacher learning, teacher practices

## INTRODUCTION

Professional development (PD) should be ongoing and related to practice while supporting active, engaged, and social learning (Garet, Porter, Desimone, Birman, & Yoon, 2001; Matos, Powell, Stajn, Ejersbø, & Hovermill, 2009). Yet, considerable amount of researchers argue that most teacher PD programs remain separated from everyday practice, reinforce the delivery of information from a provider to the professional who is positioned as being in 'need' of development (Garet et al., 2001, Hall, 2009; Jaworski, 2009; Silver, Clark, Ghouseini, Charalambous, & Sealy, 2007; Webster-Wright, 2009). These 'training' programs are argued to provide a PD experience that has limited impact on teachers (Little, 1993).

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### **State of the literature**

- Practice-based professional development (PD) models advocates for learning within social practices.
- Being a participant of social practices learners in these models are encouraged to participate into the inquiry of their practices to own and develop their knowledge.
- Practice and discourse are highlighted as new units of analysis for the inquiry of learning in mathematics education.

### **Contribution of this paper to the literature**

- We propose a particular methodological approach that contributes to research-based understanding of teacher learning at a discursive level.
- In doing that we argue that teacher practice is a frame of meaning based on teacher discourse(s) where changes/ shifts in these discourses are ways to understand about teacher learning.
- Findings showed that the teacher in this study developed new understandings in the forms of

Professional development (PD) models addressing learning within social practices are also known as practice-based PD models (Guskey, 2002). These models are often called *sociocultural* where learners are participants of social practices; encouraging participation into the (inquiry of) practice for teachers to own their knowledge and to develop an inquiry stance to teaching (Dana & Yendol-Hoppey, 2014). Furthermore, what teachers say and how they say it within classrooms is believed to play an important role on students' learning of mathematics (Ryve, 2013). Accordingly, practice and discourse are highlighted as new units of analysis for the inquiry of learning in mathematics education. However, inspite of the near consensus on ideas that describe the characteristics of effective professional learning and change, there is still ambiguity for predicting teacher learning based on these characteristics (Opfer & Pedder, 2011).

The purpose of this paper is to propose a particular methodological approach that contributes to research-based understanding of teacher learning at a discursive level (i.e., how changes/shifts in teacher discourses help to understand about teacher learning during inquiry of own practice). Hence along with the current emphasis on language and its use in mathematics education, we treated the situation as an open call for the exploration of teacher learning at a discursive level. Framing teacher learning as changes in teacher discourses, this study is anticipated to be useful for the refinement of the current approaches to teacher learning and professional development experiences for the mathematics education researchers and practitioners in order to develop new understandings around a discursive approach to teacher learning.

In the next section we first present the main ideas and the literature by which we grounded our framework on and the framework itself is presented. Then we illustrate how the framework was employed to trace teacher learning in a year-long interpretive single case

study involving a high school mathematics teacher learning in and from practice while inquiring her own practice. We employed interpretive methods of analysis (Bevir & Rhodes, 2002) to propose a methodology to investigate teacher learning in and from practice while inquiring into her own practice. In doing that we grounded on the premises that teacher practice is a frame of meaning based on the discourses of *action* and *reflection* (Mohan, 2011) where changes in these discourses may constitute learning in and from practice (Sfard, 2008; Wickman & Östman, 2002).

## THEORETICAL FRAMEWORK

The theoretical approach in this paper presents investigation of teacher learning in and from practice comprising teacher's discourses of knowing (i.e., teacher's accounts about own practice) and doing (i.e., mathematical talk and action within the classroom). Although a lot can be learned from practice, learning is usually replaced by habits gained from unquestioned practices (Schön, 1983). Beyond proposing teacher's practice as a resource of inquiry for teacher learning, the PD approach presented in this study offers a way to think about teacher learning discursively. Such an approach not only would provide a conceptual lens to capture the modification of discourses in and from practice as instances of teacher learning but also would provide teachers with the opportunity to learn from their own experience and communicate on their own terms (Kieran, Forman, & Sfard, 2001), facilitate teachers to engage in ongoing inquiry of their own practice (Day, 1999), and help to break habitual routines in the comfort zone of the teacher where they do not necessarily think about their own practice at all (Spicer, 2011).

### Teacher Learning and Practice

For the last two decades, perspectives on learning with universally governed rules for knowing/knowledge to remain the same once acquired, across different social, cultural, and historical settings have been problematized by the sociocultural approaches that view learning as becoming a *participant* in the collective doing (Kieran, Forman, & Sfard, 2001). In the seminal work of Lave (1996); practice, working, and learning are not seen as separated. Vygotsky (1978) claimed that "the dialectic unity [between speech and practical action] in the human adult is the very essence of human complex behavior" (p.24). This participationist vision notes language as a mediator for learning by assuming that meaning occurs in social contexts through the *use of language as a social practice* (Halliday, 1978). Wittgenstein (1953) also states that practice precedes understanding by saying "let the use teach you the meaning" (p.212). All of these influential ideas acknowledge social nature of human thought and emphasize the *use of language and practice* as ways of doing in the processes of learning.

Taking the 'acquisition' (i.e., learning as acquiring knowledge where knowledge is a kind of material in the human mind as a container, learner as a receiver and owner of this material) and 'participation' metaphors of learning (i.e., learning and thinking develops from a patterned collective activity viewing development of humans as the transformation in the forms of human doing rather than people themselves) into account (Sfard, 2008), teacher's

learning can be conceptualized as a combination of a “static knowledge” (of what is possessed/ individualistic) and “dynamic knowing” (of what is part of an action/collective) (Cook & Brown, 1999). In this context, there is a need to capture a new understanding of how a mathematics teacher’s learning in and from his/her practice could be investigated.

We use the phrase ‘*learning in and from practice*’ to stress the distinction between the two related challenges of teacher learning: Learning by experience and the divide between knowledge and practice (Even & Ball, 2009). While the former is based on experience stressing out learning in action acting right away which we know that experience do not always help to teach the subject to the students, the latter is about formal knowledge gained or opportunities to learn related to the work of teaching does not always connect to teachers practice. Among many other processes or tools to learn from practice based on the ideas of “reflection” in this study we stress thinking deliberately about the practice and what to do next time and inquiring own practices of teaching.

### **Teacher Learning and Discursive Perspective**

The epistemological underpinning of sociocultural perspective for learning is that knowledge is not a possession of an individual and that knowing is a consequence of a constant relationship between individual and the social practices in which one takes part. In the teaching profession, *knowing in practice* is distributed among all participants of the professional practice (i.e., students, teachers, and the other physical and conceptual resources at hand) (Kelly, 2006).

The term teacher’s knowing is used as learning in and from teacher’s practice(s) based on the teacher discourses within these social practices. The discourse here refers to the language in use. This implies that the discourse is broader than texts (i.e., sentences and utterances) including the contexts where the language is used (Halliday, 1978). Meanings are made through language as constructed and constrained by its environment, particular situations under certain circumstances. In some approaches to discourse, it is also viewed as a way of representing knowledge about a particular topic about a particular moment (e.g., see Foucault, 1970).

It is common to define communication as the exchange of meanings between individuals through a common system of symbols, signs, or behavior (Communication, 2015). Language is an important means of communication. According to (Bakhtin, 1986), the use of language/discourse is either *univocal* or *dialogic*, where the former works for *conveying meanings* (i.e. conveying information adequately from the speaker/sender to the audience/receiver) and latter opens up possibilities *to generate new meanings* that is to inform own understanding from the *other’s thinking* in the dialogue (i.e. to take an active role of constructing ideas collaboratively by questioning and extending them and informing own understanding from the others in the dialogue) (Knuth & Peressini, 1998; 2001). Knuth and Peressini (1998) suggest that teachers should watch and analyze video episodes of their own classroom instruction to understand the complexities or obstacles to foster dialogic

discourse. Boaler (2002, 2003) drew on different types of agency and described good mathematical classroom discourse and concludes that within such a discourse students take initiative, demonstrate human agency, and use the “I” voices about language and mathematics when participating in the classroom discourse. Similarly, Wagner (2007) argues that teachers make students to get an increased sense of human agency while doing mathematics by providing them with the opportunity to develop in expressing agency in mathematical language where in order to do that they would need to hear their teachers to use expressive voice (i.e., the “I” voice) in their mathematical practice. Finally, as an integral part of any communicative action, listening and how we do listen matters when thinking about mathematical discourse and communication. Davis (1997) has put that there are three modes of listening such as, *evaluative* (i.e., listening for the correct answer only), *interpretive* (i.e., listening for making sense of student thinking), and *hermeneutic* (listening for questioning oneself about ways of participation/contribution in the collective action for both parties of communication). Knuth and Peressini (1998) also use *dialogic listening* covering some aspects of interpretive and hermeneutic listening.

In this study, *teacher discourse* refers to both what teachers do and say, contributing to and as related with teacher’s mathematical practices. These discourses of the teacher comprise of knowing about own mathematical practice and doing mathematics within own classroom practices. Moreover, *learning* was studied at a discursive level where the shifts/modifications in these discourses were taken as the instances of learning. It is this discursive approach that distinguishes this study from other studies that have investigated teacher practices with an acquisitionist epistemology focusing mainly on what teachers can and cannot do within their mathematical practices (e.g., Ball, Lubienski, & Mewborn, 2001; Cochran-Smith & Lytle, 1993; Franke, Carpenter, Levi, & Fennema, 2001; Schöenfeld, Minstrell, & Van Zee, 2000; Stigler & Hiebert, 1999); or teacher learning from self-study or own practice (e.g., Austin & Senese, 2004; Hoban, Butler, & Lesslie, 2007; Ticha & Hospesova, 2006). Teacher learning from self-study or inquiry of own practice has various benefits for the teacher (Austin & Senese, 2004). Self-study supports the improvement in practice for practitioners who aim to learn about themselves at their workplace (Austin & Senese, 2004; Loughran, 2004), as they reflect on their own conceptions about teaching, learning, and practice by systematically inquiring his practice (Cochran-Smith & Lytle, 1999), where they could communicate with their own terms in the research process (Kieran, Forman, & Sfard, 2001). Self-study would also provide additional insights for teachers about their roles as educators when they watch their videotaped practices to reflect on their practice (Tischa & Hospesova, 2006). However, as there are multiple perspectives that might be influencing teacher learning in and from practice, in this study, we adopt Opfer and Fedder’s (2011) position that learning is a “complex system” comprising various influential elements of contexts of situations and /or systems as well as the individual teachers, activities or programs which are relational, reciprocal, and nested. Likewise, rather than taking individualistic and collective lenses for learning separately we aim to look at the interactions between these perspectives to bring them into a unitary whole in a similar way to the notion

of a complex system. Thus, the main reason for conceptualizing teacher learning as a social practice and aiming to understand this “practice” through discourses in this study is to contribute to a more unitary and a participative understanding of teacher learning.

Focusing on teacher discourses of knowing and doing as two complementary components of teacher’s mathematical practices, the approach in this study involves a major distinction from the approaches mentioned above, in providing a more unitary description of the learning taking place. This is also aligned with the sociocultural view that learning is highly dependent on the context and is variable and continuous across time and space just as discourses that are in a state of constant flux and transformation. Accordingly, the discursive approach explained in this paper is argued to be beneficial at providing understanding and hence for exploring the discursive mechanisms involved in teacher learning.

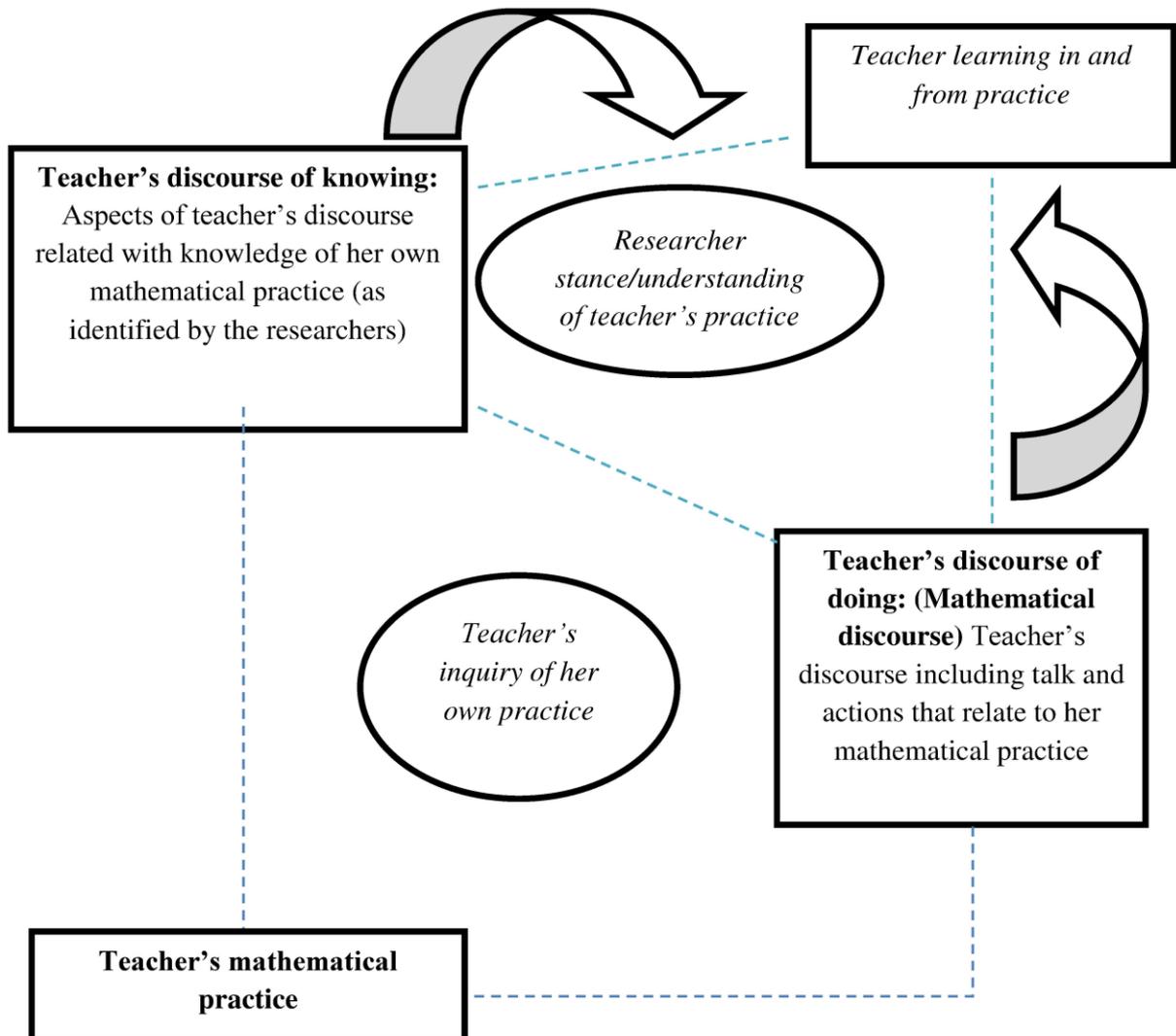
The perspective of teacher learning in this study emphasizes both the theory and practice of teacher learning along with two levels of investigation. As presented in **Figure 1**, the theoretical framework used in this study investigates teachers’ practice to understand how teachers learn in and from practice. In this representation, the teacher’s mathematical practice is studied from two complementary standpoints: (i) the teacher’s own inquiry of self-practice, and (ii) the researchers’ inquiry of the teacher’s practice. The latter is twofold, because researchers should both capture the process of the teacher’s inquiry of own practice and make sense of what this inquiry says about teacher learning in and from practice. Along with these purposes we utilized teacher’s discourses of knowing and doing mathematical practice and illustrated how changes in these discourses may constitute learning.

In line with the sociocultural tradition, this study recognizes that human thinking is situated in social practice and these practices can be explored through the dialectic of theory and practice of knowing and doing (Martin, Nelson, & Tobach, 1995) and hence learning can be traced at the level of social constructions (Myers, 2009) among which language is the most prevailing form of meaning (Halliday, 1994). Additionally, participationist discourse on learning views human development as the transformation in the forms of human doing, rather than people themselves (Sfard, 2008). So, rather than pointing out the lack of knowledge of teachers or the areas that need to be developed in their practices, this study suggests a path to trace teacher learning through teacher’s discourses in and from his/her practice as the main resource and the context for teacher learning. In particular, for mathematics education, this study suggests studying teacher learning at a discursive level by exploring the teacher discourses of knowing and the doing of mathematical practices as the teacher inquiry of own practice proceeds (see **Figure 1**).

## METHODOLOGY

### The Participant

Mary (pseudonym), a secondary mathematics teacher, was the sole participant of this study. She had 19 years of experience as a high school mathematics teacher and had been



**Figure 1.** An interpretive methodology for the investigation of teacher's mathematical practice and learning in and from that practice

working at the same school for the last eight years at the time of data collection. Located in a large urban district, the school had 84 teachers and 1,394 students, with an average class size of 40 students. Mary was selected as the participant for this study based on her willingness, being considered as an experienced teacher, having participated in professional development or training activities before, and having a clear desire for professional development and learning.

## Data Collection

Throughout the study, Mary conducted an inquiry into her own mathematical practices. Focusing on Mary's mathematical practice, data was collected through videotaped observations conducted once every two weeks, monthly audio taped interviews, and from her reflective notes. A pre-study interview was conducted where she had identified a learning theme for her inquiry in order to focus upon and took reflective notes on what happened in the classroom on that day about the theme.

The pre-study interview was aimed to help Mary to reflect on her expectations from a professional development point of view, to prioritize her needs, and finally to identify a focus of inquiry. The theme she had identified was "mathematical communication" with three sub-goals :*(i)* Getting students to understand mathematical language and definitions ;*(ii)* getting students to use mathematical language correctly and efficiently ;*(iii)* having students explain their mathematical actions, and increasing student participation.

The observations took place in three 11<sup>th</sup> grade mathematics classes during the first school semester and second school semester. There were about 40 students in each of the classes observed. Reflective notes were taken about teacher's discourse as talk and actions during and after observations and also after the interviews as field notes in order to have a sense of our voices as researchers, our thoughts and emotions, and our beliefs and biases about and during the fieldwork. Following each classroom observation, she filled out a reflection form comprised of guiding questions aimed to initiate a reflective mode for her thinking of and doing her mathematical practices. These questions or statements were derived from the main themes that have emerged from the teacher's monthly objectives. Inherently, they reflected the researchers' interpretations of these themes and mathematical communication as Mary's foci of inquiry. Main observation data reported in this study were from the first and the last observations, where approximately six months had passed in between and one more observation which was in between these two from the 4<sup>th</sup> month in the study. While the first and the last observations how the shift/change in Mary's discourse of action/doing within the classroom throughout the study, the middle one was chosen to show that the change did not occur at first.

Moreover, data from six monthly audio taped interviews (particularly from the first, the second, and the fourth one where there was a remarkable change in Mary's discourse of knowing) conducted through reflecting upon the selected episodes from videotaped observations that included critical incidents from the lessons. The critical incidents were considered as the moments which teacher feels she is the most and the least effective as a teacher and were basically identified from videotaped observations via a form we gave to the teacher to fill in weekly. Along with using Cobb's (2011) questions to identify, these incidents were also derived every once in a while, during the after-observation conversations about what happened in the class that day. During the interviews, Mary was also revising and rewriting her monthly objectives as the final step for the inquiry process she was conducting

on her own. Taking this step, Mary was expected to reflect on in order to elaborate on what had happened and why, based on her monthly objective(s) on her main theme of inquiry. Finally, although Mary's discourse of knowing, derived from the interviews, shifted clearly at the 4th month, there was not a simultaneous shift in her discourse of doing at the classroom which indeed we could identify a change in a way at the end of the 6 months period of study. Other data sources included personal communications with Mary regarding the school context and her own evaluations about monthly objectives.

### **Data Analysis**

The ideas developed by the teacher as her discourse of knowing, regarding her practice at the interviews. In these interviews, she told her stories about the video episodes from her mathematics classes and her monthly objectives. As people create meanings by recreating their own stories, storytelling is a means of knowledge production (Fraser, 2004; Ponte, 2001). Hence we analyzed those teacher stories by utilizing narrative inquiry.

Narrative inquiry uses stories as data or product and gives the researcher access to how participants interpret their reality since no one has a direct access to the participants' experiences (Riessmann, 2008). As the first step in conducting narrative inquiry all interviews were treated as interpretive stories involving teacher narratives elicited by in-depth interviewing. The interviews primarily aimed to identify the teacher's discourse of knowing (about practice); in this case, knowing about mathematical practice. We identified teacher's knowing about mathematical practice as the teacher's accounts of what happens in her classroom: how and what she perceives and how she makes sense of, think about, and respond to situations as she perceives them (Simon & Tzur, 1999, p.254).

The interviews also served to identify the teacher's focus of learning, monthly objectives, and her epistemological stance of teaching and learning. After locating the teacher stories from the interviews and giving them an initial title that reflected the main point of the story, the transcribed material was sent to Mary, the teacher, for her comment and feedback. She commented that stories and their organization made sense to her and that she did not want to correct, add, or remove anything. Upon forming the first draft of the interpretive story/narrative for each interview, through an open coding process story titles were listed in chronological order and some titles were revised as emergent codes from these stories. In doing that, each interview data was reinterpreted by focusing mainly on the words use and their meanings in order to expose any contradictions or common themes across the stories. On the other hand, the stories were also examined in order to identify self-talks, stories involving others beyond the teacher as the storyteller, and references the teacher made to related cultural conventions and discourses (e.g., the university admission exams or the school as a cultural institution would set the norms of and supporting or hindering teaching, learning, and professional development practices). Finally, six interpretive stories comprising the main themes representative of the teacher's accounts of practice were constructed. These three main themes were the discursive practices of the mathematical

classroom (i.e., the norms and epistemological underpinnings of doing school mathematics), inquiring own practice as a form of PD and teacher learning in and from practice. In line with our purpose to investigate teacher learning during the inquiry of self-practice, this study reports only on “teacher’s learning in and from practice” theme, comprising of knowing about listening and participation into mathematical practice.

The analysis of Mary’s discourse of doing, mathematical discourse, from the classroom observations was mainly drawn on discourse characteristics from the commognitive framework (Sfard, 2008). This framework was chosen, since it was developed based on analyzing mathematical classroom discourse comprising of general characteristics (i.e., word usage, visual mediators, routines, and endorsed narratives) of any type of discourse. The particular vignettes for this analysis were chosen as representative of the whole school year. Firstly, vignettes were divided into episodes involving sequences of events that had relative independence with a clear beginning and an end (Van Dijk, 1981). Then, they were analyzed in terms of Mary’s mathematical word use in terms of what they actually meant as they were used in the mathematical discourse in the classroom, how she facilitated the construction of mathematical narratives (e.g., mathematical theorems and/or definitions), and when and how she used mathematical routines (e.g., patterned recursive mathematical actions like utilizing triangles or equations in problem solving and doing calculations etc.). In terms of semiotics (Halliday, 1978), such characteristics of discourse are experiential meanings associated to particular classroom contexts and thus they were also considered together with the responsive talk and actions of Mary’s students.

To capture Mary’s learning in and from practice, the transitions or shifts in Mary’s discourses were analyzed by employing interpretive methods of data analysis. Teacher interviews and classroom observations were combined in order to bring about a participationist perspective of teacher learning as a social practice. Further validation was established through member checking by having Mary review a draft report of the results and interpretations. In order to ensure a potential transferability beyond the case, a situated generalizability was applied based on practice-based evidence (Simons, Kushner, Jones, & James, 2003).

## FINDINGS

### **The Teacher’s Discourse of Knowing**

Mary’s discourse of knowing about her practice was mainly framed around her learning theme: mathematical communication. The reason for Mary’s choice of ‘mathematical communication’ as her focus of inquiry was evident in her statements about student’s understanding of mathematical definitions and language.

*Everything is hidden in definitions. In general, they are neglected by the students. Students mostly cannot use them [the definitions] correctly. Most of my students are very bad at listening and writing. They also have knowledge deficits; they can’t*

*see certain things, and how we can overcome them? The more we practice, the better they are able to see things. What is given and which to apply in which situation? (Interview #1)*

During the interviews, Mary often referred to the rules of participation in mathematical practices within the classroom. The rules included listening to the teacher, taking notes, attendance, proper ways of asking questions, practicing (key) questions and exercises determined as imperatives for doing and learning mathematics within the classroom. Furthermore, Mary considered mathematical expressions, procedures and students understanding of and learning to use them as a high priority since they lead for a higher achievement in university admission exam. She also clearly talked about her teaching in an authoritative way; teaching as the resource of all information, and for much of the talking and mathematical actions within the classroom:

*Teaching should be the teacher's responsibility. You give essential definitions, solve sample questions (...) the teacher should be the leader. (Interview #1)*

*It is the teacher's responsibility to give the **essence** of the subject [bold for emphasis]. The teacher generally transmits, but students may generate different solutions. The teacher should be the one who gives rise to ideas. (Interview #2)*

According to these accounts, Mary's teaching conformed to a traditional lecture format, where she did most of the mathematics on the board by talking, solving questions, and giving examples, whereas the students' participation was limited to solving these exercises and answering questions prompted by her.

Another important point to note about Mary's discourse of knowing was her frequent use of "understanding of mathematical definitions and language", associated with practicing and solving exercises from a workbook prepared for the university admission exam. As she stated many times before, her main concern here was to prepare students to solve test items faster in order to get higher scores in the university admission exams.

### **The Teacher's Discourse of Doing: Mathematical Discourse**

The following vignette from the first lesson observation illustrates Mary's mathematical talk and action about quadrilaterals. During the lesson, Mary encouraged her students to participate in solving a problem about carrying out of a procedure that ends up with finding possible values of  $x$  (see [Figure 2](#)) in a quadrilateral ABCD. As a beginning Mary utilized a visual representation of a quadrilateral given in the problem and started with a query comparing possible values with a single value.

Mary: According to the figure [referring to **Figure 2**] what are the possible values of  $x$ ?

...[Silence]...

Mary: Okay. We have always found single value [bold for emphasis] for the problems we have solved up until now. It says: '**possible values of  $x$** '. Under which condition this can be like that?

At that part, Mary's attempts were for her students to recall a mathematical narrative: the triangle inequality. When Mary reminded them about using triangles in the mathematics classroom for solving questions, some students could recall and relate with the triangle inequality.

Mary: We solve [such]questions by using triangles in general, don't we? Does this ring a bell?

Students: There was... an inequality.

Mary: Yes, the triangle inequality! Do you remember[what it is]?

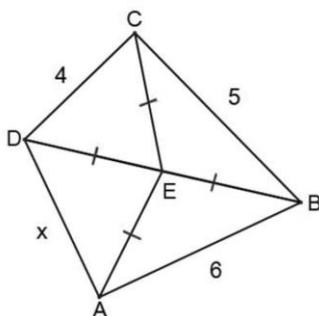
Student 4: If we know two sides, then we can find the middle  $x$  by taking both the sum and difference of them.

Mary: How can we? What could that middle  $x$  be?

Student 4: It is bigger than the sum of the two, but smaller than the difference.

Mary: We were recalling the triangle inequality. The three numbers that I wrote would not always construct a triangle. Then we could only find values more than one. Then we need to use that.

As illustrated in this vignette, recalling of a mathematical narrative first and then implementing it on a problem was a common type of routine in Mary's mathematical discourse. Mathematical narratives were constructed within the classroom as a warm up routine before heading to a new subject. However, the construction process was not collective, since Mary intervened in the process almost every time which resulted in minimal



**Figure 2.** The quadrilateral problem discussed in Mary's classroom [figure reproduced]

student participation in the construction. This was in line with Mary's discourse of knowing about mathematical practice in a traditional lecture format. On the other hand, Mary's routine of *using triangles* seemed more of a ritual and representative of her discourse of doing. Her *using triangles* routine was ritualized, since it depended on situational and contextual factors such as solving test items for the university admission exam. These routines were also further validated institutionally and culturally other than the classroom. On the whole, Mary's opt for utilizing mathematical rituals instead of producing mathematical narratives was an integral part of her mathematical discourse. Accordingly, students were expected to perform mathematical procedures mainly based on Mary's, the teacher's, prompts.

### Stability of the Teacher's Mathematical Discourse

There was not any significant change in Mary's mathematical discourse within the classroom for some time. The following vignette about logarithm functions is from fourth month of the study.

Mary: Now let's give one or two more property. [*Writing the following on the board:* 8)  $a^{\log_a b} = b$  9)  $a^{\log_b c} = c^{\log_b a}$ ]

Student 1: Is there any other property?

Mary: No, we will not do any more. OK, now, how are we going to use these properties in questions? Let's see that. [*After searching for exercises from the textbook*]Let's start. What is  $216^{\log_6 5}$ ? We need to try to get rid of logarithms in all questions, don't we? But how?

Student 2: By using 8 [*Referring to the 8th property written on the board.*].

Mary: By using what? Using 8<sup>th</sup> will work for us. Is 216 a power of 6?

Students: Yes.

Mary: The third, then what happens? Does it come to that,  $6^{\log_6 5}$ ? And what now? In the expression above logarithm comes to the head as a multiplier.

Student 3:  $3^5$

Student 2:  $5^3$

Mary: Which one?

In the dialogue above, Mary delivers the properties of logarithm functions as mathematical narratives to her students and expects students to implement these as a procedure into exercises. In both vignettes above her discourse did not allow a collective construction of these narratives and there had been no increment in the student participation since the first lesson observation 4 months ago. While the majority of the class remained

silent, those who had talked were not clear on how they thought mathematically. Here we also observe that Mary's discourse relied much on performing rituals as 'trying to get rid of logarithm in all questions' (as in using triangles) with limited student participations where only 3 or 4 students spoke but they didn't contribute much to discourse which is being formed within the classroom. Although she asked questions, these were prompts calling students to act in certain ways.

### **The Shifts in the Teacher's Discourses: Changes in Meanings in Light of New Experiences**

Similar to the classroom observations, during the first four or five months of the study there was no notable change in the use of Mary's language regarding the mathematical communication at the interviews where she watched her classroom video episodes. In the 4th interview there was an apparent shift in her discourse.

*I realized [bold for emphasis] that in the past I was not listening to students; impatiently completing their answers or comments. Now I am more cautious to let them to finish their words... When we decided to work on mathematical communication, the first thing that came to mind was that the teacher leads the flow of communication. They [the students] would consult me when they felt stuck and frustrated. On the contrary, I was telling and showing them everything then...I was so burn out by trying to manage all, flow of the communication. Now I feel more comfortable and content about my teaching...This is something that I discovered at my 19<sup>th</sup> year. (Interview #4)*

In that interview, we observed a transformation at Mary's *discourse of knowing* about practice new themes such as *listening to students* and *new ways of participation into the mathematical practices* emerged. This new *knowing* about listening and participation also revealed throughout the course of Mary's mathematical discourse, during her own inquiry of practice.

The following vignette about mathematical sequences is from the final lesson for about eight months after the first lesson observation.

Mary: What is the 6<sup>th</sup> term of the sequence whose general term is  $\sum_{k=1}^n \left(\frac{1}{2}\right)^{k-1}$ ? What does it mean here, the 6<sup>th</sup> term?

Students:  $a_6$

Mary: OK, how do you get that?

Student1: We may subtract those till  $a_5$  from those to  $a_6$ .

Student2: No, it comes directly from the formula.

Student3: Isn't it to write 6 in place of  $n$ ?

Student1: But, there is a sum here.

Mary: Yes, but...

Student1: Just a minute ago, when I wrote 6, it gave me the sum of those that are from 1 to 6. If I write...

Mary: I don't want the sum of the terms from 1 to 6, I want the 6<sup>th</sup> term.

Student1: I got that, but I will write those from 1 to 6 and then subtract those which are till 5 so that only the 6<sup>th</sup> term remains. Otherwise...

Student4: OK now, teacher. When we do it from 1 to 6, we will find the sum of the terms up to 6.

Student5: No, it says sum, otherwise it would not have said *sum*. [Italics added for emphasis]

Student6: Can it be like that? [*In response to the Student4's explanation*]

Mary: Please don't confuse it with the sum of the terms.  $a_n$  given as the summation symbol.

Student1: I don't understand that teacher! Should it not be like from 1 to 6, since there is a sum symbol?

Student9: Does it ask only the  $a_6$  or the sum?

Student4: Wouldn't it be ok if we find 6 and then subtract 5?

Mary: But what you wrote here are not the terms of the sequence; it is the sum of the  $k$ 's. OK let's see what it is like. I mean  $a_5$  is from 1 to 5,  $a_6$  is from 1 to 6. If the lower bound was  $a_n$  then you were right. OK? But the thing stated here is different.

At that point the discussion moved on among the students. There was a huge noise in the classroom where each student was talking to one another. Mary seemed a little uncomfortable about the situation that arose in the classroom. Nevertheless, she let them talk for a few minutes. Finally, a student stepped forward telling she was willing to explain her thinking on the board.

Student7: I give values from 1 to 6 for  $k$ . [*Writes simultaneously*]

Student8: And this is 63 over...

Student7: OK now, let me finish!

Mary: Do we have an induction formula here or am I wrong?

Student7: Yes, we have!uhmm...1 minus r to the power n over 1 minus r. I write  $\frac{1}{2}$  in place of n and...[Completes the rest of the operations]

Mary: We can find the solution directly from here. Now, let's make that clear. If it was  $\sum_{k=1}^n a_k$  then it would be the sum from k is equal to 1 from n. Some of you have said that, but it asks only the 6<sup>th</sup> term, not the sum. Let us elaborate more on that at the sum of the first n terms of the arithmetic and the geometric sequences.

In this vignette, from the last lesson observation, notable changes and shifts in Mary's mathematical discourse were observable. Apart from the decrease in talking within the lesson, her mathematical routine was exceeded mere transmitting the essence of the subject. First, she provided a space for the discussion of the arguments about the problem at hand. She was aiming for her students to realize the difference between their thinking and the problem situation by probing the meaning within and did this step-by-step with limited interference. Second, in explaining their solutions and their thinking students started to talk more by using mathematical language. They also started to take initiative and explain their thinking with their own voice. During classroom discussions some of the students even tried for possible alternative explanations to the problems other than the one that Mary provided. Yet, Mary was not aware of that fact and these students neither were able to tell it to her nor they were able to explain it in front of the class. Although students' thinking was mathematically different than Mary's and some of their arguments were wrong, this was a critical point which had implications both for Mary and her students. Here, although Mary's and her students' mathematical discourse were still incompatible, the way that she undertook the situation differed significantly than she did in the very first lesson observed in this study.

## DISCUSSION AND CONCLUSIONS

In this study, viewing teacher learning from a window of development and transformation of teacher discourses, teacher learning was conceptualized as a social practice having its own discourses of knowing and doing (Mohan, 2011). While the teacher's *discourse of knowing* was her own accounts about her mathematical practice formed mainly at the interview setting, *the discourse of doing* comprised of the teacher's mathematical talk and actions during her mathematical practice at her classes. Accordingly, in order to learn about the teacher's learning in and from own practice we propose an interpretive methodology to investigate teacher learning through discourses of doing and knowing, and how these discourses change. Utilizing a discursive mechanism, it was demonstrated that the teacher in this study developed a new understanding during her inquiry of own practice about mathematical communication in the forms of changes in her meanings about listening and participation.

Changes in the use of words (i.e., discourse) generate new meanings associated to these words (Wittgenstein, 1953). Around the fifth month of the study Mary, the teacher, presented

changes within her *discourse of knowing* which were mainly listening to her students and her participation into the mathematical practices. This shift was based on her reconsideration of the old meanings and understandings throughout her learning pathway with a new awareness of herself and of her students as others. Furthermore, this awareness resulted with an increased sense of responsibility regarding her own path of professional learning that was also reflected in her discourse of knowing. As a result, new meanings about listening and participation of students and the teacher into the practice were created through her experience of self-inquiry of her own practices. After a while, this change was also evident at her discourse of doing or her mathematical discourse within the classroom. In her discourse within the classroom, for instance, a shift could be traced in her ways of listening to her students that became more interpretive rather than evaluative as she began to listen to her students by asking questions to understand *their sense making* about an arithmetic sequence problem (Davis, 1997). Moreover, students increasingly using their expressive voices (i.e., the “I” voice) that demonstrated human agency and taking initiative to participate into the discourse were signs of good mathematics discourse (Boaler, 2003). Human agency in talks about mathematics was also a sign that the students were making something happen and/or doing mathematics (Wagner, 2007). The shifts in these forms of student participation could be understood as part of the collective activity of emerging new forms of participation into the discourse where the teacher’s discourse of doing mathematics is the instigator that makes it happen.

Although new meanings emerged through Mary’s discourse of knowing, the significant change in her mathematical (doing) discourse was about two months later than that. Nevertheless, this does not mean that there was not any change in her discourse of ‘doing mathematics within the classroom’ throughout the two months period. In fact, about a month earlier after we identified the shifts we mentioned above in her discourse, there were actually instances of shifts in her mathematical discourse in the classroom. We observed that, for instance she made exploration routines available for her students so that they constructed new mathematical narratives about polygons.

Moreover, throughout her inquiry, Mary’s mathematical (doing) discourse within the classroom evolved towards a dialogue between herself and her students towards a more dialogic one allowing for the generation of new meanings (Bakhtin, 1986; Knuth & Peressini, 1998, 2001). She mainly did that by starting to emphasize more on the meanings rather than procedures associated with the problem situations that led to a discursive conflict between herself and her students. For instance, as illustrated in the last vignette presented above, although Mary expected the students to notice the structure of the formula for  $a_n$  in a way that each term is constructed for different values of  $k$  (i.e., 1, 2, 3 etc.) the students considered the general term of the sequence  $a_n$  as the sum of the terms from 1 to  $n$ . This conflict might have stemmed from different realization procedures of the teacher and the students. Creating a discursive conflict among the discussants based on the different discourses of the teacher and her students formed a communicational breach for the learning to come alive,

which is considered crucial for learning school mathematics (Sfard, 2008). Additionally, the discursive conflict in the second vignette could be viewed to help negotiating different (mathematical) meanings of the teacher and the students where “different communities of discourse are in some sense meeting” (Moschkovich, 2007, p. 26).

In this study, from a Wittgenstenian sense, we associated changes in meanings with the shifts in the teacher’s discourses of mathematical practice. We believe that it is difficult to understand any development or change regarding individuals without considering them in a collective activity in which they participate (Sfard, 2008), which in this case is *doing mathematics within the classroom* or mathematical classroom practice. In addition to teacher’s self-inquiry of practice, using discourses as the unit of analysis allowed us for tracking changes in the *forms of teacher’s doings* not only at an individual level (i.e., watching video records of her classroom episodes and reflecting on her own practice) but also at a collective level (i.e., teacher’s teaching and student learning mathematics within the classroom) while the teacher focuses on her own theme of inquiry. One might argue that this study is only about an individual teacher inquiring own practice, where not any collective level (i.e., joint reflection or collective inquiry) exists. However, from a sociocultural point of view, teacher learning or knowing is shared and distributed among all participants of the discourse (Kelly, 2006). Thus, teacher’s new understanding regarding listening and participation cannot be fully understood as such by individual discourse of knowing. For that, adopting a participationist lens (e.g., see Sfard, 2008) and exploring teacher’s discourse of doing mathematics within the classroom was also needed in order to make sense of these meanings at a collective level. By looking at individual and collective discourses as different toolboxes and complementary levels to investigate teacher learning in and from practice; in this study, we aimed to bring about a unitary conceptualization of teacher learning. In doing that we strived for explanations about the interactions between these two complementary levels of the practice rather than focusing on the invariance of the structures that influences learning (Opfer & Fedder, 2011) and rather than pointing out the lack of knowledge or need for development at an individual level only.

The methodology presented in this paper strives to pay utmost attention to situational-contextual aspects of practices that unfold teacher’s learning. Approaches considering these aspects are questioned for not dealing with the continuity of learning and how new meaning is generated by the transition of old meanings (Halldén et al., 2002). In response to this, in our conceptual framing we view meanings as changes and transformations within and among the teacher’s discourses of knowing and doing regarding mathematical practices in a way that connects the past discourses to the present, and hence to those of the future that are developing. For instance, we traced the shifts in Mary’s discourses of knowing and doing almost simultaneously evolving from a *generic declarative form*, accompanying a traditional authoritative discourse within the classroom, towards a *generative self-oriented* one as Mary listens to her students and creates new ways of participation for her students and herself. Focusing our attention to continuum of teacher’s past and present discourses we believe, that

we attend to notion of the *historical continuity of discourses* allows for and carries knowledge accumulation and makes it possible to capture regeneration of meaning from the old ones for investigating practices a sociocultural unit of analysis (Foucault, 1970). Grounding on the continuum of discourses, the methodology also presents a chain of causality that Opfer and Pedder (2011) spoke of, in terms of developmental change of these discourses that would not have otherwise been captured by focusing the individual and collective elements of learning. Hence shifts in Mary's discourse of knowing were changes of old meanings in light of her new experiences regarding participation into the mathematical practice (Wickman & Östman, 2002).

### LIMITATIONS OF THE STUDY

Regarding discourse developing in and from Mary's classroom practice we acknowledge that there would have been other factors related to her practice that might have affected the results. One such factor, for example, would be considered the content being thought as the vignettes presented in this study cover a range of different topics from geometry to algebra. However, in contrast to the most professional development and teacher knowledge/learning literature, the teacher in this study did not learn about any mathematical content as it was evident from both of her discourses. We considered mathematical communication as a frame of learning independent from the content for two reasons. First, since this was a self-inquiry of practice the general frame of the teacher learning was determined as mathematical communication by her at the beginning of the study. Second, since this was a year long study we knew that the content would change. She was an experienced teacher and she did not declare any sort of preference to learn about mathematical content during the personal conversations or interviews. Hence the focus of the analyses and the interpretations was not on the content.

Reporting on a single case might also be considered another limitation. In addition, we could not have presented a collectively generated, "socially shared and distributed across participants and resources" (Kelly, 2006, p. 510) aspect of teacher learning framework precisely, at least in the absence of other teachers. Despite these limitations, this study could provide an internal generalizability that can be extended to other cases. In fact, findings presented in this paper are in line with the idea of situated generalization (Simons et al., 2003) that the transfer of knowledge from one context to another takes place while experience turns into evidence, considering the process as a fundamental aspect of one's own practice based on interpretation and judgment of oneself and of others. Hence, interpretations of teacher learning in this study are based on the teacher's own interpretation and reinterpretation of her own experience in particular situations, which were derived in and from her practice, together with our perspectives and interpretations as researchers that would collectively validate new learning according to the contextual criteria.

## RECOMMENDATIONS

It is important to note that for teachers inquiring their own practices, there is a natural tendency of seeing one's own practice in the groove based on habitual experiences and routines. Although it might take some time to get out of those *comfort zones*, both focusing on their conversations and self-talk about their own practice, and more specifically how we use mathematical words and how we create and bring mathematical narratives and routines in action, might help them a lot to look at the ways of learning in and from practice. Furthermore, since self-evaluation of our own work is always limited to our own understanding, teachers might gradually seek to expand their inquiry to a collegial level with whom they have a relationship based on trust and professional respect and even towards a more collective level to conduct research and share their experience with teachers in other schools (Simons et al., 2003). Instead of beginning to conduct an inquiry of own practice alone, teachers can have a teacher from their school or from another school who they feel like they can work and cooperate easily. On the one hand, they might document their own inquiry; on the other hand, they might simultaneously observe, reflect and communicate about each other's process. By the time they gain confidence in working with others, they might be ready to work with more teachers.

It is also important for the mathematics education researchers to consider while using the methodology presented in this study that there are at least two levels of inquiry which are constantly interacting with each other. Even though we illustrated the teacher's own inquiry and the researcher's inquiry of the teachers practice as primary investigations in **Figure 1**, researchers should always be aware that there should be a subtle secondary analysis and interpretation of the inquiry of the teacher's inquiry. Additionally, although it might seem that there is no apparent shift in any of the discourse for a while, there might be promising evidence for shifts in teacher discourse(s) when the analysis is performed as the basis of continuity and the coherency of the discourses. Those issues might be even more crucial for further research using this methodology when studying group of teachers inquiring their own practice learning in and from practice at a discursive level, or the way that social and pedagogical meanings are generated through teacher discourses associated with mathematical practice that the teacher(s) might learn in and from practice.

Apart from proposing a discursive lens for understanding teacher learning in and from practice as discussed above, the methodology presented in **Figure 1** is promising as it provides the interaction and the combination of these subsystems. Combining the teacher and her forms of learning through knowing and doing discourses provided us with the explanations or causes in different levels that may lead to teacher learning where some of them were identifying preconditions and catalysts for learning or others giving reasons for the way that the learning occur and so on. This adds an explanatory causality based on the recognition of multiple processes and mechanisms via two main discourses that may produce teacher leaning which is missing in many teachers learning study (Opfer & Pedder, 2011). Hence, the discursive lens opens up the possibilities to understand teacher learning as

a complex multifaceted system, rather than the reductionist way that treats it as a product of a professional development process, or over-simplifying it by focusing on only one element, system or measure of learning.

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