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Using classroom discourse to understand a prospective mathematics teacher's developing practice[☆]

Maria L. Blanton^{a,*}, Sarah B. Berenson^b, Karen S. Norwood^c

^aDepartment of Mathematics, University of Massachusetts Dartmouth, 285 Old Westport Road, North Dartmouth, MA 02747-2300, USA

^bCenter for Research in Mathematics and Science Education, North Carolina State University, Raleigh, NC 27695, USA

^cMathematics, Science, and Technology Education Department, North Carolina State University, Raleigh, NC 27695, USA

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Abstract

This is an interpretive study of a prospective mathematics teacher's emerging practice during the professional semester. A Vygotskian (Mind in Society, Harvard University, Cambridge, MA, 1978 (Cole et al., Trans.; original work published 1934); Thought and Language, Massachusetts Institute of Technology, Cambridge, MA, 1986 (Kozulin, Trans.; original work published 1934)) perspective was used to examine the nature of classroom discourse and its role in Mary Ann's (pseudonym) development while student teaching. Results indicate that early classroom discourse mediated Mary Ann's teaching toward a traditional paradigm of giving information. Moreover, her subsequent efforts to cultivate dialogic discourse generated conflict that positioned students as mediators of her practice. Ultimately, experiencing the power and diversity of students' ideas contributed to shifts in Mary Ann's early forms of practice. © 2001 Elsevier Science Ltd. All rights reserved.

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In recent years, the preeminence of constructivism as an epistemological orientation in mathematics education has directed much attention toward understanding how students construct mathematical knowledge (e.g., Cobb, 1995; Cobb, Yackel, & Wood, 1992; Steffe & Tzur, 1994;

Thompson, 1994). This focus has often led to interpretive inquiries into classroom discourse as researchers have sought to explicate the nature of students' mathematical thinking (e.g., Cobb, 1995; Cobb, Boufi, McClain, & Whitenack, 1997). We see a continued emphasis on classroom discourse as pivotal to current reforms in mathematics education because discourse informs not only our understanding of students' thinking about mathematics, but also teachers' thinking about teaching mathematics. As such, our purpose here is to look more closely at linkages between classroom discourse and learning to teach mathematics. Recent studies in the professional development of mathematics teachers (e.g., Cobb, Wood, Yackel, & McNeal, 1992; Cobb, Yackel, & Wood, 1991; Peressini

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*Corresponding author. Tel.: +1-508-999-9171; fax: +1-508-910-6917.

E-mail address: mblanton@umassd.edu (M.L. Blanton).

& Knuth, 1998; Wood, 1995; Wood, Cobb, & Yackel, 1991) have broadened our understanding of the importance of classroom discourse as it relates to (inservice) teacher learning. For example, in Wood's (1995) interactional analysis of a classroom teacher's practice, discourse was viewed as giving voice to the social complexities inherent to teaching in a collective setting. Moreover, discourse provided a verbal window into that teacher's developing practice by documenting patterns of interaction between teacher and students as they negotiated their roles in the classroom.

The genre of research on inservice teacher development in situ used by these and other scholars suggests an interesting parallel for the study of prospective teachers during the professional semester (i.e., student teaching practicum). The professional semester offers an optimal context in which knowledge of mathematics, of teaching mathematics, and of learning mathematics coalesce into an emerging practice for the student teacher. As such, this context invites intense scrutiny in order to understand the process of becoming a teacher. In this study, our curiosity centers on understanding the nature of classroom discourse¹ and its concomitant role in one mathematics student teacher's developing practice. Specifically, this research addresses the following questions:

1. What is the nature of discourse in one mathematics student teacher's classroom?
2. What can be inferred from the discourse about that student teacher's developing practice?
3. How is that student teacher's practice mediated through such discourse?

1. Teacher learning through classroom discourse

We used Vygotsky's (1978, 1986) sociocultural approach, which prioritizes the role of discourse in an individual's development, to conceptualize this study. Vygotsky maintained that "higher voluntary

¹ Since the notion of classroom discourse may connote a variety of meanings, it is specified here to denote talk, or utterances, made about mathematics by teacher and students in the classroom.

forms of human behavior have their roots in social interaction, in the individual's participation in social behaviors that are *mediated by speech* [italics added]" (Minick, 1996, p. 33). He extended this idea in his "general genetic law of cultural development", which posits that an individual's higher mental functioning appears first on the intermental plane, between people, and is then genetically transformed to the intramental plane, within the individual, through a long series of developmental events (Vygotsky, 1978; Wertsch, 1988). Through this transformation, or *internalization*, an external operation is internally reconstructed. The significance of this perspective is that it extinguishes traditional boundaries between individual and social processes in order to forge a view of mind constituted by both (Wertsch & Toma, 1995). That is, Vygotsky's belief in the social origins of higher mental functioning embeds human consciousness in "the external processes of social life, in the social and historical forms of human existence" (Luria, 1981, as cited in Wertsch & Tulviste, 1996, p. 54). Bateson (1972) succinctly illustrates this notion of an extended mental system:

Suppose I am a blind man, and I use a stick. I go tap, tap, tap. Where do I start? Is my mental system bounded at the hand of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of my stick? (Bateson, as cited in Cole & Wertsch, 1994, p. 3).

From this perspective, mind is seen as "distributed in the artifacts which are woven together and which weave together individual human actions in concert with and as a part of the permeable, changing events of life" (Cole & Wertsch, 1994, p. 3). Building on this Vygotskian view of social interaction in learning, we assert that in the external processes of the classroom setting the (student) teacher is also subject to this social formation of mind. That is, the teacher's obligation to manage the intermental context of the classroom as he or she engages in the activity of teaching generates opportunities for that teacher to learn as well. This suggests that a teacher's developing practice is inherently linked to the social dynamics of the classroom.

Vygotsky further theorized that, in the context of social interactions, higher mental functioning is

mediated by physical and psychological tools (Vygotsky, 1978, 1986; Wertsch, 1988). In particular, he maintained that psychological tools (e.g., language) control human behavior and cognition by “transforming the natural human abilities and skills into higher mental functions” (Vygotsky, 1986, p. xxv). It was his belief in the primacy of language as a mediating tool that drew our attention to classroom discourse as one way to explore a student teacher’s development. Moreover, concerning the role of language in development, Vygotsky reasoned that language is itself subject to mediation. Holzman (1996) explains this conundrum:

The dialectical role of speech is that it plays a part in defining the task setting; this activity redefines the situation, and in turn, speech is redefined. Language is both tool and result of interpersonal [i.e., intermental] and intrapersonal [i.e., intramental] psychological functioning (p. 91).

As we understand this, language is central in a developmental process through which it mediates higher mental functioning first intermentally, then intramentally. As language voices an individual’s mediated higher mental functioning within a task setting, the process is renewed.

This suggests to us that, as the teacher engages in some form of practice, the classroom discourse that results will influence that teacher’s intramental thinking about teaching mathematics. We find further support for this in Vygotsky’s (1986) general genetic law of cultural development. Applying this principle to the classroom, Wertsch and Toma (1995) argue that the nature of classroom discourse induces an active or passive stance on the part of the *student*. They postulate that this stance is subsequently reflected in the student’s intramental functioning as external operations are internalized. For instance, if the purpose of classroom discourse is to make sense of ideas and to use those ideas to generate new thinking, then it can reasonably be expected that students will interpret utterances as thinking devices, “taking an active stance toward them by questioning and extending them [and] by incorporating them into their own external and internal utterances” (p. 171). We submit that this

principle can be extended to the *teacher* as well. Although we recognize that the teacher is more likely to set the tone of discourse in the classroom, he or she is, nevertheless, a participant in discourse and therefore subject to its mediating effect. As such, we expect the nature of discourse to shape that teacher’s intramental thinking about teaching mathematics.

2. Pattern and function in classroom discourse

In order to address our questions about teacher learning and classroom discourse, we needed a framework for analyzing verbal interactions in the student teacher’s classroom. According to Potter and Wetherell (1987), there are essentially two phases in a discourse analysis: (1) identifying patterns of variability and consistency in the data, and (2) establishing the function and effect of people’s talk. Identifying discourse patterns led us to current literature that features analyses of classroom interactions (see e.g., Underwood-Gregg, 1995; Voigt, 1995; see also Wood, 1995). While the focus of this body of work extends beyond our particular emphasis on verbal interactions in the classroom, we found the approach used by these scholars helpful in making sense of patterns in discourse. Their perspective of analysis, rooted in the traditions of ethnomethodology and symbolic interactionism, is predicated on the notion that obligations felt by teacher and students in accordance with perceived roles in the classroom are enacted through various routines. Such routines, most often embedded in language, comprise the patterns of interaction in the classroom. For example, a teacher’s felt obligation to clarify a student’s thinking might be enacted as a routine in which the teacher asks a series of instructional questions (i.e., those for which the teacher already knows the answer (Wertsch & Toma, 1995)) designed to lead that student, step-by-step, to the correct solution. Simultaneously, the student’s obligation to give the teacher’s desired response might lead to a routine of guessing by that student. Together, these routines comprise a pattern of classroom interaction. Thus, identifying such a pattern involves constructing its constituent parts, namely,

the routines established by the teacher and the students.

To identify the function of discourse, we used Lotman's (1988) argument that text (e.g., discourse) has a dualistic structure. First, text may serve as a "passive link in conveying some constant information between input (sender) and output (receiver)" (p. 36), a function that Wertsch and Toma (1995) describe as *univocal*. In this, text is treated as information to be received, encoded, and stored. Consequently, any discrepancy between what is transmitted and what is received is attributed to a breakdown in communication. Moreover, questions that may arise as a result of a discrepancy are intended to align the speakers' codes. In contrast, text may also serve as a "thinking device" so that, rather than being interpreted as an encoded message to be accurately received, the speaker's utterances serve to generate new meaning for the respondent. In essence, text becomes a starting point for making sense of an idea or constructing new ideas (Peressini & Knuth, 1998; Wertsch & Toma, 1995). This function, which Wertsch and Toma describe as *dialogic*, is evidenced when a participant actively interprets text by questioning, validating, or even rejecting it.

3. Process of inquiry

3.1. Data collection

Thus far, we have argued that a teacher's developing practice is deeply connected to classroom discourse, and we have described a framework for analyzing such discourse. To establish this empirically, we considered the developing practice of Mary Ann (pseudonym), a prospective middle school mathematics teacher, during her student teaching semester. Mary Ann was assigned to a seventh-grade classroom in an urban school community in which she taught general mathematics and pre-algebra. Our interviews with and observations of Mary Ann indicated that she felt well suited to this placement. Moreover, she was paired with a cooperating teacher who provided a nurturing environment, sharing her own wisdom of practice without stifling Mary Ann's ideas.

We used participant observation, in-depth interviews, and artifact reviews as tools of inquiry. In particular, weekly visits with Mary Ann during the practicum were each structured as a 3-h interval that consisted of a classroom observation, followed by a teaching episode interview, and finally, a second classroom observation. Both classroom observations were of Mary Ann teaching general mathematics. The teaching episode interviews with Mary Ann were treated as a teaching experiment (Steffe, 1991), with the goal to understand Mary Ann's development over an extended period of time. There were eight visits in all, as well as a separate exit interview. Visits were documented through field notes, audiotape, and videotape. Mary Ann was also asked to provide at each visit a copy of her lesson plan along with any supporting materials, such as quizzes or activity sheets. Although these documents were viewed as secondary data sources, we could not assume that key issues might not later emerge from them. Additionally, Mary Ann was asked to keep a personal journal in which she reflected on what she had learned about her students, about mathematics, and about teaching mathematics through the course of each visit. Finally, we conducted two clinical interviews with the cooperating teacher to obtain a more complete picture of Mary Ann's classroom community.

3.2. Analysis of classroom discourse

As mentioned earlier, our analysis focused specifically on verbal utterances (see, e.g., Peressini & Knuth, 1998; Wertsch & Toma, 1995) in Mary Ann's classroom. Because such an analysis is often tedious and unscripted, we outline here the details of our process. To tease out pattern and function from discourse data, we began by transcribing videotapes of classroom observations, inserting comments and questions as they arose in transcription. In retrospect, these memorandums initiated our understanding of the data corpus. Using the conversational turn as the basic unit of analysis, we combed early transcripts of Mary Ann's teaching to identify a preliminary coding scheme that would describe the purpose of her utterances. The codes reflected Mary Ann's expectations of students as participants in mathematical discourse, thereby

providing an initial insight into her thinking about teaching mathematics. For example, her questions “What’s the common denominator between 6 and 2?” and “How did you figure out that 6 was the common denominator?” were coded as “Request for Computation” and “Request for Procedure”, respectively. From this preliminary scheme, codes were refined or discarded, and new codes were added as subsequent data were analyzed.

To code the transcripts, each classroom observation was divided into manageable sections based on naturally occurring divisions in the sequence of classroom events. These divisions were signaled by a change in theme or direction, such as when class discussion on a particular problem concluded. Sections were then coded by conversational turn, and the essence of interactions between Mary Ann and her students was abstracted to get a sense of the routines and patterns in the discourse. Additionally, sections were compared in order to ascertain similarities and differences that suggested changes in Mary Ann’s practice. The coding system represented a first attempt at sorting the data and was eventually set aside as we focused on the particulars of pattern and function in the discourse.

Once the transcripts had been coded, four classroom observations representative of Mary Ann’s developing practice were selected from one of her two general mathematics classes for further analysis. Patterns and routines in verbal interactions were identified in this subset of the data. Specifically, we considered the routine actions that Mary Ann and her students enacted after a mathematical question had been posed. Furthermore, based on Wood’s (1995) process of documenting teacher learning in the classroom, we considered shifts in pattern and function as a way to establish change in Mary Ann’s pedagogy. Sections from transcripts of the four classroom observations were subsequently selected as representative of the routines and patterns manifested in the discourse. These sections were then further analyzed to characterize the function of discourse as univocal or dialogic. Since function is identified by a respondent’s passive or active interpretation of a speaker’s utterance, it was necessary to consider each speaker’s utterance and how it was subsequently interpreted by the respondent. Other data sources (e.g., journal reflections)

were perused for confirming or disconfirming evidence concerning assertions generated through our analysis.

4. Findings and interpretations

4.1. *Early pattern and function in classroom discourse*

In this section, we discuss through transcription and analysis the nature of early discourse in Mary Ann’s classroom and what we infer from this about her emerging pedagogy. The following excerpt occurred during a lesson on solving simple, linear equations that we observed on our second visit to Mary Ann’s classroom. We include it here as representative of the ways that Mary Ann and her students talked about mathematics during what we characterize here as her early practice. (This period spanned approximately the first month of her student teaching.) As was often the case when working problems through whole-class discussion, Mary Ann recorded mathematical pieces of the conversation on the overhead projector (OP) as students spoke. (All names are pseudonyms.) She read the following problem to the class:

Alex had \$5 left in his wallet after he spent \$12 on snacks and souvenirs at the Jubilee. How much money did he take to the Jubilee?

- 1 Teacher: How much money did he spend?
- 2 Jim: Twelve dollars.
- 3 Teacher: Twelve dollars. OK, if he spent \$12, would he be minus or plus?
- 4 Students: Minus.
- 5 Teacher: Minus. He’s going to be minus. So how much money he took to the Jubilee is an unknown. It’s something that we don’t know.... So, how do we represent unknowns?
- 6 Students: Variable.
- 7 Teacher: A variable. OK, what variable do [you] want to use?
- 8 Mark: *M*.
- 9 Teacher: OK, so *m* is the amount of money he has, and how much did he spend?
- 10 Carol: Twelve.

- 11 Teacher: Twelve dollars. And how much did he have left over?
- 12 Students: Five.
- 13 Teacher: (Mary Ann writes the equation ' $m - 12 = 5$ ' on the OP to be solved.) OK, what was the very first step [in solving this equation]? What was the very first step that I gave you yesterday Chad?
- 14 Chad: Isolate the variable.
- 15 Teacher: Isolate the variable. OK, how did we isolate the variable?

At this point, students began calling out random responses, including “subtract 12 from both sides of the equation”. They seemed to be applying a procedure used in the previous day’s lesson, in which a class of equations was solved by subtracting a (positive) constant from both sides of an equation.

- 16 Teacher: OK, here we already have subtraction (indicating the symbol ‘ $-$ ’ in ' $m - 12 = 5$ '), so what’s the opposite of subtraction?
- 17 Students: Addition.
- 18 Teacher: So if I want to make a zero here, what can I do?

Once more, students offered various responses, including again ‘subtract twelve’.

- 19 Student: Subtract twelve.
- 20 Teacher: If I subtract twelve, it’s going to be a plus minus and a plus minus, so I didn’t make a zero. So how am I going to get rid of the subtraction?
- 21 Student: Add.
- 22 Teacher: Addition. So what am I going to add?
- 23 Student: Twelve.
- 24 Teacher: OK, do I add it to one side or ...?
- 25 Student: All sides.
- 26 Teacher: Both sides. OK, so I have a minus twelve plus twelve, and what is that?

Students again called out various (inaudible) responses, none of which were zero.

- 27 Teacher: Zero.
- 28 Karl: It’s 24. You’re supposed to add twelve.

- 29 Teacher: OK, this is not an addition sign right here (indicating the symbol ‘ $-$ ’ in ' $m - 12 = 5$ '). It’s a subtraction sign.
- 30 Karl: I know.
- 31 Teacher: If you make it plus the opposite, I have a minus twelve plus a twelve. What is that?

Another student suggested zero and, after Mary Ann again attempted to explain the error in Karl’s thinking, she continued in this manner to the solution of the equation.

As depicted in this exchange, Mary Ann’s approach for working math problems was to herself establish the direction for solving the problem, initiating what we describe as an “incremental questioning routine”. That is, she fractured the content by asking a series of simple, closed, leading questions (e.g., 3, 5, 16)² that funneled students toward a final answer. Embedded in this structure were Mary Ann’s routine actions of supplying students with explanations of her own methods (20) or with hints that would prompt students’ recall of procedures (13). Moreover, in completing their part of the routine, students responded to Mary Ann’s prompts by guessing (“subtract twelve from both sides”) and giving short answer responses (e.g., 21, 23). We observed the typical early pattern of classroom interaction to be structurally equivalent to a pattern described elsewhere as “Initiation–Reply–Evaluation” (Mehan, 1979). In Mary Ann’s case, the pattern included the following sequence:

- teacher writes the problem/exercise on the OP and initiates the direction for solving the problem by giving information and asking leading questions;
- student gives a rote response, guesses a response, or performs a computation set up by the teacher;
- if the student gives an incorrect response, the teacher may give hints or offer an explanation in order to get a particular response;
- if the student gives the desired response, the teacher may repeat the student’s response and then ask a leading, follow-up question.

² Numbers in parentheses refer to lines in the protocol.

We characterized the function of discourse in this episode as predominantly univocal. This can be seen in a general sense through Mary Ann's reliance on instructional questions (e.g., 16, 18, 20, 22, 24, 31), which Wertsch and Toma (1995) link to a univocal function of text. Other specific utterances support this interpretation as well. For example, Mary Ann seemed to assume from Karl's incorrect response (28) that her original question (26) was either inaccurately transmitted or received. In essence, she interpreted his utterance (28) as a breakdown in communication. We infer this from Mary Ann's attempt to align her code with Karl's by explaining her own perspective (29, 31), rather than questioning his utterance. Yet, Karl's utterances (28, 30) imply that his question was not about the operative symbol, as Mary Ann supposed. As Mary Ann concentrated on demonstrating her methods in other parts of this episode (e.g., 20), she asked questions for which the purpose seemed to be to check accuracy in her transmission of procedural information (e.g., 22, 24). Moreover, when students incorrectly applied a procedure, Mary Ann explained her own perspective (16, 20) rather than question students' responses in order to generate new ideas or to make sense of their strategies.

What can we infer from classroom discourse about Mary Ann's early practice? First, Mary Ann's felt obligation to clarify students' responses (e.g., 20) positioned her as the filter of discourse. That is, she directed the exchange, deciding what type of questions to ask and when and to whom to ask these questions. Indeed, Mary Ann's routine of affirming a student's correct response, or of meeting incorrect responses with hints and explanations, depicted a norm of doing mathematics in which students looked to the teacher, not to their peers, to explain, justify, or reject their ideas. Moreover, rather than exploring students' strategies, Mary Ann seemed intent on showing how she would have worked the problem. Ultimately, she, not students, produced the model " $m - 12 = 5$ " for the problem task (13). Although it seemed to us that Mary Ann genuinely wanted students to participate, she relied on questioning strategies that required students primarily to compute simple answers, recall information, or describe procedures pre-

viously learned (e.g., "What was the very first step that I gave you yesterday?", "What is minus 12 plus 12?"). At this early stage in her practice, it seemed inherent in Mary Ann's practice of teaching to be the center of information for her students, to weed out responses that did not follow a teacher-selected path for solving the problem at hand, and to help students avoid the struggles that do (and should) accompany mathematical inquiry.

4.2. *On early discourse and Mary Ann's practice*

The pattern and function observed in early discourse in Mary Ann's classroom is not unlike that outlined elsewhere in the case of inservice mathematics teachers (see, e.g., Bauersfeld, 1988; Peressini & Knuth, 1998; Underwood-Gregg, 1995). Moreover, given Mary Ann's perspective of mathematics as "just operations you go through, just like a series of steps [where] you have to step on this step before you get to the next one" (Interview), it was not unexpected that such discourse characterized her early practice. What struck us was that the nature of early classroom discourse itself also seemed to structure her pedagogy, calling our attention to Vygotsky's (1978, 1986) belief that language plays a dialectical role in an individual's development. In particular, early classroom discourse seemed to mediate Mary Ann's pedagogy toward a more univocal paradigm of giving information and inspecting the accuracy of transmission. This is not to say that models of teaching she may have internalized before the professional semester did not also inform her practice. However, our teaching episodes with Mary Ann revealed pieces of the pedagogy she was internalizing *through the intermental context of the classroom*. In particular, she commented about her early practice, "I just didn't anticipate ... having to break things down, and going over it, and over it, and over it ... It's just, you know, drilling it over and over". By this, we suggest that through discourse with her students, Mary Ann was "learning" to ask cognitively simple questions (e.g., 1, 7, 9, 20) that funneled students' thinking in a certain direction. In turn, these questions were often easily answered by students (e.g., 2, 8, 10, 21), which seemed to further validate Mary Ann's

approach. For questions that were not easily answered (e.g., 15, 18), Mary Ann fractured the content into more manageable pieces (16), or gave her own explanation (20). In other words, as participants' reactions in an activity establish meaning for that activity (Vygotsky, 1978), so it seemed that students' reactions in doing mathematics gave meaning to Mary Ann's early pedagogy.

4.3. *Indications of an emerging practice: change in pattern and function*

4.3.1. *The problem-solving day*

Over our first several visits, we sensed a momentum developing in Mary Ann's classroom in which univocal functioning dominated discourse. For us, this intensified the need to address Mary Ann's pedagogical thinking in the context of her teaching, where such discourse occurred. The opportunity came during our third visit with Mary Ann, later monikered the "problem-solving day" because the lesson focused on the strategy "working backwards" as a way to solve simple word problems. Although the pattern and function that typified early languaging in Mary Ann's classroom persisted to an extent throughout the practicum, events on the problem-solving day did substantiate her attempt to shift from discourse grounded almost exclusively in univocal functioning. Mary Ann had insisted during the teaching episode on this particular visit that she was uncomfortable with word problems and did not want to teach this lesson. Moreover, having taught the same lesson in the class prior to our teaching episode, she conveyed to us the sense that her current pedagogy (involving traditional forms of discourse) did not lead to student understanding. As a result, we used the teaching episode to encourage Mary Ann to alter her approach to this lesson. In particular, we suggested alternatives and then structured the discussion so that Mary Ann could share ownership of the ideas.³ The following excerpt, which occurred during this discussion, was based on our classroom observation immediately prior to this teaching

episode:

32 Interviewer: When you put the [word] problem on the board, ... you began to talk to [students] about how to do that problem. Do you think it might be a good idea to let them struggle with it? Is this the kind of problem where you could let two or three [students] work together and try to figure out how to do it and see what kind of method they [use]?

33 Teacher: That could be an idea. Maybe I could let them work with the person beside them.

When Mary Ann expressed concern that this social organization might lead to classroom management problems, we steered to other subjects and, later in the teaching episode, returned to this topic.

34 Interviewer: So would you be comfortable if you [had] students work [a problem] for a while and try to figure out how to come up with a solution?

35 Teacher: Yeah. That's how I'm thinking about starting the next class ... Just have [a] problem on the board and then tell them to solve it. Don't introduce anything about working backwards.

36 Interviewer: This would be very different from what you did [in the previous class].

37 Teacher: Right, because I did talk about working backwards. And [I would] have [students] work with each other.

Reflecting on the way she had previously approached this lesson, Mary Ann commented:

Probably just the fact by me telling them this is the way we're going to do things today, ... then they automatically think, well I've got to figure out some way to work backwards, so I confine them to thinking of one solution.

During the class following the teaching episode, it seemed to us that Mary Ann took considerable

³ For a more detailed treatment of the nature of the teaching episodes, see Blanton, Berenson, and Norwood (in press).

risks to cultivate a different form of discourse. She began by placing students in dyads to solve the following problem:

I'm thinking of a number that if you divide by three and then add five, the result is eleven.

Mary Ann encouraged students to struggle with the problem through peer interactions and justify their solutions to one another before she joined the process. This met with immediate resistance from students as, almost imperceptibly, their role in doing mathematics had shifted. Once again, Mary Ann was a participant in a verbal interaction that could have mediated her pedagogy to a more traditional approach. The following exchange illustrates the tension created by her efforts to redefine teacher and student roles in problem solving.

38 Teacher: OK, I want everybody to work with a neighbor I want everybody to read this and solve it. Work with your partner. If you feel like you need to write it down, write it down. I just want you to solve it.

At this point, students began raising their hands with questions for Mary Ann, instead of consulting their peers.

39 Teacher: I'm not going to answer any questions, just solve it. (Speaking to Trish, who tells Mary Ann she has the answer) Well, that's good. You need to write it down and tell me how you solved it. (Speaking to the class) You should be talking with your partner.

Once again, Trish asks Mary Ann to check her solution.

40 Teacher: I'm not going to tell you if it's right or wrong. I want you to work it out. (Speaking to another student asking for help) Did you consult with [your partner]? Does she think that's right? (Students began raising their hands again.) No hands up. Just talk about it [with your partner]. (Speaking to a pair of students) Have you figured it out and you both agree?

This tension eventually dissolved as students, realizing Mary Ann's intentions, began to communicate about the problem with each other.

The whole-class discussion that followed reflected another shift in Mary Ann's practice, as she pointedly asked different groups to share their solutions, and later their strategies, with the class. Noting the first group's correct response and immediately moving to others for their results, Mary Ann appeared more interested in students' responses than just correct answers.

41 Teacher: O.K., our first group to finish was Debbie and Susan, so they're going to tell me the number they got. (She writes their response "18" on the OP.) O.K., (turning to another group), what did you get?

42 Group: Six.

43 Teacher: O.K., what number did you get, Jack?

44 Jack: Eighteen.

45 Teacher: (Speaking to another group) What number did you get?

46 Wendy: I got 38.

At this point, Mary Ann asked Debbie to explain her (correct) solution of 18, to which Debbie responded with the strategy she used (47).

47 Debbie: It says, "If you divide by 3 and add 5", so you do the opposite. You subtract 5 from 11 and that's 6. Then you multiply 6 times 3 and that's 18.

48 Teacher: O.K., you just taught our lesson for today, oddly enough. That's exactly what we're going to learn how to do today.

Mary Ann's response (48) registered genuine surprise that a student had so succinctly captured this problem-solving strategy. (Unfortunately, transcripts strip the dimensionality of actual dialogue.) It seemed to us that this interaction, and Debbie's response (47) in particular, enabled Mary Ann to continue to reorganize the way she talked about the problem with her students. For example, as the lesson continued, Mary Ann seemed to stop focusing on transmitting her own strategies and began

focusing instead on how her mathematical thinking was demonstrated in students' strategies. This included asking several groups which had made unsuccessful attempts at solving the problem to explain their strategies as well, reflecting a departure from a practice in which Mary Ann rarely countenanced incorrect answers.

- 49 Teacher: (To another group) How did you get 18?
 50 Jill: We had a number. We said 18 divided, 3 will go into 18 six times. Then we added 5.
 51 Teacher: O.K., so first of all you knew that the result had to be 11, so you said, "O.K., it's 11". Then I told you you had added 5, so you had to think, what added to 5 will give you 11. O.K.? I'm trying to ... think like you were thinking. Is that what you did?

After Jill affirmed this, Mary Ann turned back to the class.

- 52 Teacher: O.K., who got 38? I'm curious to see. (To Mark) Tell me how you got 38.
 53 Mark: I did s over 3.
 54 Teacher: You did what?
 55 Mark: S over 3.
 56 Teacher: O.K., what now?
 57 Mark: Equals 11.
 58 Teacher: So what happened to the 5?

As Mary Ann tried to make sense of Mark's solution through questioning, he seemed to recognize the error in his thinking. We contrast this with an episode from early classroom discourse (28–31), in which Mary Ann assumed a telling, not questioning, stance to address a student's incorrect thinking. Mary Ann continued to reorganize class discussion about the problem by positioning Debbie as the mathematical authority, thereby relinquishing a role that typically Mary Ann seemed obligated to fill.

- 59 Teacher: The way Debbie chose to do the problem is what we're talking about today. She, well Debbie, you

tell me what you did. Is there any certain way you can call maybe what you did, without using the book? When you looked at this problem, where did you start?

- 60 Debbie: Where did I start? I started at the answer.
 61 Teacher: You started at the answer and then did what?
 62 Debbie: And then I just went backwards.
 63 Teacher: O.K., did everybody hear what she just said? Debbie, repeat that one more time.
 64 Debbie: I started at the answer and worked backwards and did the opposite of, uhm, division and addition.
 65 Teacher: So Debbie used a problem-solving strategy of working backwards. That's just one strategy. Some of you used guess-and-check, and maybe you didn't come up with the right answer, but you were on the right track. Some of you set up an equation.

This comment (65) seemed to capture another shift in Mary Ann's thinking. Her discomfort with exploring various routes to a task's solution seemed evident in early discourse where she, not the students, determined the solution path. Her comments in the teaching episode prior to this class confirmed this. She explained,

I guess to me, like, I was always, give me a formula, or give me a way to solve it, and I'll solve it. And sometimes with word problems there's [*sic*] many different ways ... That puzzles kids to think there might be more than one way. It always scared me ... If I know that there ... is more than one way, that scares me. That's weird, I know, but I feel like if there's one way, I can check it, and if I get it right, then I'm right, and I'm right, and I'm right. That's all there is to it.

That she was now willing to relinquish the one strategy she was comfortable with by the inclusion of other valid processes (65) seemed a significant shift for her. We emphasize that, while we had

encouraged Mary Ann to explore students' strategies, and her stated intent was to do so, the discursive events in the social context of the classroom ultimately gave meaning to this practice for Mary Ann. As the interaction revealed to Mary Ann the power and diversity of students' ideas (48, 65), she seemed to appreciate students' contributions to the discourse. Her reflection about teaching this particular lesson confirmed the change in her thinking, reminding us again of pieces of the pedagogy she was internalizing *through the intermental context of the classroom*. She wrote:

[At the beginning of the lesson], instead of throwing information out, I let them figure the problem out in their own style.... To my surprise, one of the students performed the problem exactly as the strategy suggested. Boy, was this a memorable event. The pressure was lifted off of me.... Once the students saw how one of their peers was able to solve the problem, things were a lot more clear to all. I learned that having the student come up with the solution means more to the others than the teacher giving a long, drawn-out lecture.

We take the events from the problem-solving day, as well as Mary Ann's written reflections, as evidence that her pedagogy was mediated toward a more reform-minded practice. More importantly, we argue that the intermental context of the classroom, specifically classroom discourse, was a factor in Mary Ann's shift in practice. In particular, where once she felt the obligation to give a "long, drawn-out lecture" by "throwing information out", she seemed to learn from interactions with students the value of students working through a process with their peers and collectively sharing their results. We could only point Mary Ann in this direction. It took her classroom experience to give meaning to this approach. The pattern and function in discourse, which we consider next, gave us an additional perspective on this transition.

4.3.2. *Pattern and function on the problem-solving day*

The routines enacted by Mary Ann and her students in this episode differed from those observed in her early practice. Rather than giving hints and

questioning incrementally to lead students to a correct solution, Mary Ann enacted what we describe as a "solicitation routine". In other words, she initiated the discussion by soliciting solutions and strategies from students rather than focusing on her own perspective. Consequently, in the absence of Mary Ann's earlier routines such as giving hints, students no longer seemed obligated to try to guess her thinking, but could instead share their own perspectives. The resulting pattern of interaction that we observed in this episode reflected a more interactive form of languaging than that expressed in previous classroom discourse. While this pattern was not fully adopted on the problem-solving day, it seemed that the experience of students being more actively engaged in discourse opened Mary Ann's thinking to the value of such interactions. It included the following sequence:

- teacher writes the problem on the OP and asks students to work in dyads for a solution;
- teacher asks various dyads for their solutions;
- student representative of each dyad responds;
- teacher asks various dyads to explain their strategy;
- student representative of each dyad responds;
- teacher questions dyads for clarification;
- teacher summarizes students' strategies.

In addition to a transition in Mary Ann's routines, the function of discourse surrounding the problem also reflected a variation from that of early languaging in her classroom. In particular, there seemed to be an underlying shift away from instructional questions, which Wertsch and Toma (1995) link to a univocal function of text, to questions that explored students' solutions and strategies (41–46, 49–58). Moreover, we suggest that while Mary Ann would have previously interpreted incorrect responses as the result of a transmission error (i.e., univocally) which she was obligated to correct by demonstrating her own strategy (20), on the problem-solving day she began to question students in an effort to make sense of their strategies (52–58). Although she still seemed primarily concerned that students understand the procedure of working backwards, we suggest that the discourse that occurred on this day was for Mary Ann a developmental step in cultivating dialogic discourse. If she

had maintained a fixation on her own perspective, we question if students would have participated as they did. In turn, through the process of students sharing their own strategies, Mary Ann, perhaps inadvertently, was opening the door for dialogic interactions.

4.4. *Moving forward in classroom discourse: learning to listen*

After the problem-solving day, there were occasions when the nature of classroom discourse reflected the type of languaging we had observed in Mary Ann's early practice. For us, this underscored the fragile nature of the student teacher's development within the classroom. However, an episode several weeks after the problem-solving day made a compelling argument for Mary Ann's continuing effort to cultivate a different form of discourse. On this "pattern-finding day", students worked in dyads to investigate the number of diagonals in various polygons. Geoboards were used to model the specific cases. After tabulating students' results for a triangle, quadrilateral, pentagon, and hexagon, Mary Ann asked students to find a pattern in order to predict the number of diagonals in a heptagon. The following excerpt chronicles part of the whole-class discussion surrounding this activity.

- 66 Teacher: So does everybody have a prediction, or has formed a hypothesis?
 67 Students: Yeah.
 68 Teacher: Did you test it to see if it works?
 69 Ralph: Yeah, it works.

At this point, Mary Ann asked four student dyads for their solutions, enacting the solicitation routine she had used on the problem-solving day. Although these students gave correct solutions, it was John's (incorrect) response (72) that got her attention.

- 70 Yue: People are raising their hand with the same answer.
 71 Teacher: Well, that's fine. I want to hear what everybody says.
 72 John: I think 12.
 73 Teacher: You think 12? ... Do you have something to back up your predic-

tion? [Some way] ... to test your hypothesis?

- 74 John: I did, but it's wrong.
 75 Teacher: Well, maybe not. Maybe if we test it. Lisa?
 76 Lisa: I have 12.
 77 Teacher: O.K., so Lisa and John think it's 12. O.K., so John and Lisa, ... tell me how you got 12.
 78 John: Well, each one of those says increased by, uhm, a number higher than each other, but ...
 79 Teacher: O.K., I didn't understand that. So, you must have said that not in my lingo. So, break it down.

As John attempted to explain his thinking, Mary Ann interrupted.

- 80 Teacher: Whoa! O.K., so you go ...
 81 John: You increase [the number of diagonals in a triangle] by 2 [to get the number of diagonals in a quadrilateral], then you add another one and increase again by 2 [to get the number of diagonals in a pentagon]. [The number of diagonals in a quadrilateral will] increase by 3.
 82 Teacher: O.K., so tell me. [The number of diagonals in a triangle] will increase by 2. So we increase by 2 here (referring to the number of diagonals in a triangle). Now tell me where I go from there.
 83 John: Then you add 1[to the number of diagonals in a quadrilateral] and increase by 2 again. Then [the number of diagonals in a quadrilateral] increases by 3.

John's pattern was based on the difference in the number of diagonals in successive polygons. From this, he could determine the value to add to the number of diagonals in a hexagon in order to predict the number of diagonals in a heptagon.

- 84 Teacher: O.K., so you're saying [that the number of diagonals in a quadrilateral] is increased by 3. So you add one to the former (that is, you add

one to the number of diagonals in a quadrilateral to get the difference between the number of diagonals in a quadrilateral and that in a pentagon)?

85 John: Yeah, and you keep doing that.

86 Teacher: So then what would your number be here (indicating the number of diagonals in a heptagon), if your prediction is you add one [to the difference between the number of diagonals in successive polygons] for every time you add one here (indicating the number of sides of the polygon)?

87 John: Fourteen. (His previous solution was 12.)

At this point, Mary Ann turned to the class to elicit a symbolic representation of the pattern. She argued,

If your hypothesis is correct, you've got to back it up mathematically. So you've got to show me an equation that can back this up You're mathematicians and you're scientists, and if somebody asks you to test . . . and formulate your hypothesis, you've got to have some way to back it up. I didn't say this (i.e., 14) is right. I said this is what you're making me buy into, or selling to me.

Mary Ann and her students continued with this rich discourse for the remainder of the lesson. The univocal discourse that characterized early language in Mary Ann's classroom was tempered in this episode by her efforts to interact dialogically, as she encouraged students to hypothesize and justify their thinking with mathematical evidence in order to solve a non-routine problem. In particular, Mary Ann's tendency in her early practice to ask leading questions that demonstrated her thinking was replaced in this episode with a purpose to make sense of students' strategies and to use their responses as a springboard for extending the mathematics. She seemed to be learning to listen to her students dialogically. That is, she seemed to be listening in order to generate new understanding, not just determine if information had been correctly transmitted and received. For example, (79) and

(82) suggest that Mary Ann treated John's utterances (78, 81) as a thinking device as she tried to make sense of his alternative solution to the problem. We contrast this with the episode from her early practice (e.g., 20) in which Mary Ann addressed incorrect responses with her own explanations. In fact, throughout the pattern-finding discussion, Mary Ann never shared her own perspective. Moreover, she used John's correct solution (87) as a starting point for students to generate a symbolic representation of the pattern ("If your hypothesis is correct, you've got to back it up mathematically . . ."), not as a point of closure for the problem. (We note that in the episode from her early practice (1–13) Mary Ann, not students, generated the model.)

The routines embedded in discourse reflected this transition as well. In (77–87), Mary Ann's early image of the teacher as a mathematical authority, obligated to funnel students exclusively to her own interpretation of a problem through such routines as giving hints and incremental questioning, seemed to expand to include a perception of the teacher as an arbiter of students' ideas, obligated to solicit students' strategies and explanations as a platform for resolving mathematical questions and extending students' mathematical thinking.

In concert with Peressini and Knuth (1998), we wish to clarify our position that univocal discourse does have its place in the classroom, albeit not at the expense of dialogic discourse. Their conclusion that "all dialogic text must contain some univocal functioning in order for clear communication to take place" underscores the functional dualism of text argued by Lotman (1988). However, as evidenced by Mary Ann's early practice, there is a need to cultivate balance in the function of discourse so that dialogic interactions constitute a meaningful part of that discourse. Mary Ann's later practice, reflected in the pattern-finding day, seemed to edge toward that preferred balance in which univocal and dialogic forms of discourse dualistically exist.

4.5. Mediation in the intermental context of the classroom

To complete our analysis, we turn again to the question of how classroom discourse shaped Mary Ann's pedagogy. We should note first that during

the teaching episode on the pattern-finding day, we did not discuss in detail with Mary Ann how conversation about the polygon problem might emerge, or how Mary Ann might support this. Her stated intent was to let students determine a pattern for the number of diagonals in a polygon “because then they could come up with it ... just like [on the problem solving day when] I tried [this approach] and the kid solved it” (Interview). We analyzed classroom discourse for additional insight as to why this discussion unfolded as it did. As her comment above indicates, Mary Ann had already experienced the power of students’ thinking through discourse on the problem-solving day. Thus, she had the capacity for and interest in entertaining John’s incorrect solution (72–77). Moreover, we suggest that John’s act of arguing his particular approach for describing the pattern (78–87), and in the process correcting his own thinking, prompted Mary Ann to push students to further justify their particular pattern (“If your hypothesis is correct, you’ve got to back it up mathematically You’ve got to show me an equation that can back this up ...”). In essence, the interaction with John seemed to prompt her to challenge students to extend their justification to another level. We see this as quite different from the episode reflecting her early discourse, in which she provided the model for a word problem (13).

Looking back at the different classroom episodes shared here as representative of Mary Ann’s developing practice, we argue that she increasingly promoted a practice of teaching that centered students in the process of doing mathematics. More importantly, we suggest that the discursive act of students reasoning about mathematics and sharing their ideas helped to shape the ways that Mary Ann and her students did mathematics. No doubt, Mary Ann’s interactions with us (and with others outside her classroom) served to guide her thinking and helped her build alternative teaching strategies. We do not minimize these factors in her development, although it is not our intent to explicitly analyze them here. However, we do suggest that changes in Mary Ann’s pedagogy were not merely a function of influences external to her classroom, but were deeply connected to this setting. In particular, as Mary Ann experienced the power of students’ ideas

through verbal interactions, her perception of teacher and student roles (hence, her pedagogy) seemed to shift from teacher as teller (early practice) to student as teller (problem-solving day), to student as mathematical participant (pattern-finding day). In other words, classroom discourse helped mediate her practice of teaching. Additionally, the structure of classroom discourse, articulated here through pattern and function, reflected this transition in her pedagogical thinking. That is, language itself was mediated. In essence, language was both “tool and result of interpersonal [i.e., intermental] and intrapersonal [i.e., intramental] psychological functioning” (Holzman, 1996, p. 91). In this sense, we suggest that discourse in Mary Ann’s classroom communicated the dialectical process of development (in this case, Mary Ann’s development) set forth by Vygotsky.

5. Discussion

Shifts in teachers’ practices championed by such reform agendas as the National Council of Teachers of Mathematics (NCTM) *Professional Standards for Teaching Mathematics* (1991) might seem daunting to the student teacher rooted intramentally in traditional norms of doing mathematics. While it is encouraging to note that discourse in Mary Ann’s classroom did reflect positive shifts in her pedagogy consistent with standards articulated by such agendas, what else can we glean from her case that might apply to the broader task of teacher preparation? First, we suggest that an analysis of classroom discourse can be a catalyst for elucidating the prospective teacher’s emerging pedagogies. In particular, identifying the pattern and function of mathematical discourse in Mary Ann’s classroom provided a window into her developing practice during the professional semester. In general, by analyzing pattern and function in classroom discourse, we can get a more authentic picture of a student teacher’s internalized models of teaching than other (secondary) sources provide. As such, we suggest that the type of discourse analysis used here can be both a tool for teacher educators and a means of self-analysis for prospective teachers.

Certainly, the genesis of change in Mary Ann's practice was not confined to the intermental context of her classroom; social interactions in settings external to this domain shaped her practice as well. In fact, our purpose here is not merely to show change in Mary Ann's practice of teaching. Indeed, it would be objectionable to make inferences about the nature of her *future* practice based on a one-semester study. Our purpose, instead, is to establish that classroom discourse can act as an agent of change for novice teachers. To this end, we suggest that Mary Ann's case illustrates the potential for the dynamics of the student teacher's classroom to mediate his or her practice. This has clear implications for teacher educators. In particular, how can we provide the necessary scaffolding for student teachers during the professional semester so that they can make sense of and learn from the type of classroom discourse that characterizes their teaching practices? Research suggests that current forms of traditional supervision focus on peripheral issues of teaching and are therefore not adequate for effecting deep changes in student teachers' pedagogies (see, e.g., Feiman-Nemser & Buchmann, 1987). As such, what should a teacher educator's pedagogy resemble as a university supervisor in order to more adequately address the complexity of teacher development as it occurs in the student teacher's classroom?⁴ More research is needed to answer this question.

For us, the most serious implication of this study centers on the role of teacher education in addressing the nature of classroom discourse. In particular, we need to help student teachers cultivate a practice that engages students in dialogic, as well as univocal, classroom interactions. For the student teacher, changing the nature of classroom discourse likely requires confronting existing norms for doing mathematics. The student teacher is acculturated into a mathematical community in which students are already members and, as such, are cognizant of that community's practices of doing mathematics. This, coupled with the student teacher's sensitivity to students' experiences while under his or her

tutelage (a sensitivity that may be particularly felt by student teachers), yields a form of influence to students. The conflict that results from a student teacher's efforts to cultivate new forms of interactions places students in a position to shape the nature of classroom discourse. These experiences forge a critical juncture at which teacher educators can assist prospective teachers in renegotiating the nature of classroom discourse. Furthermore, while the professional semester invites such assistance, the nature of discourse in a prospective teacher's classroom should be addressed in earlier undergraduate settings as well. (Elsewhere, the use of the undergraduate mathematics classroom as a context for challenging prospective teachers' notions of mathematical discourse is being explored.)⁵ Indeed, the tool of language merits the same attention in teacher education that physical tools (i.e., manipulatives) often enjoy. Ultimately, the mathematics teacher's ability to cultivate serious mathematical thinking in students rests on the nature of classroom discourse.

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⁴ Elsewhere, we have used Mary Ann's case to consider this issue (see Blanton et al., in press).

⁵ See Blanton (1999)

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