ABSTRACT. Researchers agree that achieving the fundamental changes called for by current reforms in mathematics education requires new learning on the part of teachers. Currently, across the United States there exists a tremendous variety of teacher-enhancement projects representing a range of perspectives and approaches to supporting teachers’ learning. This paper presents a comparative analysis of three teacher educators using a curriculum designed for use with elementary teachers in an inquiry-group setting. The aim of the study was to examine the process and demands of supporting teachers’ learning and teachers’ efforts to reform their practices. Analyses revealed that the central demand of supporting teachers’ learning through inquiry involved navigating through what we have called openings in the curriculum. These openings took the form of unanticipated questions, challenges, observations, or actions by participating teachers that required facilitators to make on-the-spot judgments about how to guide the discourse. Examinations of the facilitators’ processes of navigating these openings revealed a set of three activities they employed in determining how to respond. Analysis of the activities of facilitators in response to openings further illuminates the work involved in supporting teachers’ learning and has implications for the skills needed by teacher educators engaged in this work.

KEY WORDS: curriculum material use, mathematics education, professional development, teacher development, teacher inquiry, teacher learning

INTRODUCTION

The images of mathematics teaching and learning envisioned by the current reform movement in the United States are foreign to most U.S. teachers. As a result, reforming mathematics education requires substantial new learning on the part of teachers (Ball, 1997; Simon, 1997). To encourage this learning, professional development opportunities for teachers also must change (Cohen & Barnes, 1993; Heaton, 2000; Sykes, 1996). In recent years, the growing body of research on teacher learning and change has provided insights into the kinds of learning that are likely to support significant shifts in mathematics teaching. Many researchers agree that teachers need opportunities to develop deep understandings

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of mathematics and of students’ mathematical thinking and development (Ball, 1993; Schifter, 1998). We have learned that teachers’ pedagogical decisions are closely connected to their beliefs about students, learning, and the aims of education (Fennema, Carpenter & Franke, 1996; Thompson, 1992). Finally, considerable evidence suggests that the kind of learning that supports fundamental change in teaching occurs over a long period of time, with extensive support and multiple opportunities to experiment and reflect (Loucks-Horsley, 1997; Nelson, 1997).

There is less agreement, however, about how to foster and support this kind of learning (Ball, 1997). Currently a tremendous variety of teacher-enhancement projects exists across the world, representing a range of approaches to promoting teacher learning and change (Loucks-Horsley, 1997). This study examines one such project. The authors studied three teacher educators using an innovative teacher development curriculum in the United States. The aim of our research was to study the process and demands of fostering learning that supports teachers’ efforts to reform their practices.

THE CURRICULUM AND THE CHALLENGE IT OFFERS

Developing Mathematical Ideas (DMI), designed by Schifter, Bastable and Russell (1999), is a curriculum intended for use with elementary teachers in an inquiry-group setting. Through cases of students’ mathematical thinking written by teachers, group discussions, and mathematical investigations, the materials provide opportunities for teachers to simultaneously examine central mathematical ideas and students’ thinking about them. The curriculum rests on an assumption that, through examining their own and children’s understandings of mathematical structures and relationships underlying the elementary curriculum, teachers will learn mathematics in new ways and reconsider what it means to learn and know mathematics. The DMI developers expect new insights teachers gain from these mathematical explorations to prompt rethinking of what it means to teach mathematics. This approach is in concert with Ball’s (1997) call for professional development to foster a stance of critique and inquiry, rather than one of answers.

At the time of the study, the DMI curriculum included two modules, “Building a System of Tens” and “Making Meaning of Operations.” Through a sequence of eight 3-hour sessions, each module chronicles the development of children’s mathematical understandings as they move from kindergarten into the middle grades. In preparation for each session, participants read teacher-narrated cases of classroom episodes that illus-
trate student thinking and work. In addition to reading and discussing cases, teachers explore mathematics for themselves, share and discuss samples of their own students’ work and understandings, view videotapes of mathematics classrooms, and write their own cases.

The DMI curriculum guides facilitators’ work by providing activities, readings, and a structure for each meeting. It also includes reflective journal entries of a fictitious DMI instructor as she guides a group of teachers through the modules. Each entry provides an image of how the facilitator interprets and reflects on the interactions of participants. Research on K-12 teachers using reform-oriented curricula, however, suggests that implementing an innovative curriculum is not simply a matter of picking it up and using it (Cohen, 1990; Heaton, 2000; Lloyd, 1999; Remillard, 1996, 1999). It involves interpreting new and unfamiliar ideas about teaching and learning. Thus, using an innovative curriculum for teacher development is likely to involve at least two layers of complexity for teacher educators. The first layer involves working with unfamiliar ideas about children’s mathematical learning. The second layer involves finding one’s way through new approaches to teachers’ learning. For this reason the DMI curriculum provided a productive site to examine the following question: What is involved for facilitators as they (a) use an innovative teacher-development curriculum and (b) support the kinds of teacher-learning opportunities compatible with reform ideas in mathematics education?

WHAT WE KNOW ABOUT CURRICULUM AND REFORM IN MATHEMATICS EDUCATION

The preceding question is related to existing research on reform-inspired teaching and teachers’ use of curriculum materials. Nevertheless, there is little research that examines such questions when the teacher is a teacher educator and students are practicing teachers. In fact, research on how teachers interact with and use curriculum materials is relatively new. Previously, textbooks and curricula were viewed as accurate representations of classroom curriculum (Walker, 1976). Implicit in this perspective was a view of the teacher as a conduit for curriculum, not a user or shaper of it. Observations of teachers using the “teacher-proof” materials of the 1950s and 1960s suggested that many teachers did not use the new curriculum materials as the authors had intended. Stake and Easley (1978) described adaptations to inquiry-based curriculum that reflected teachers’ notions about teaching and the nature of the subject matter. Sarason (1982) observed teachers’ struggles to understand the “New Mathematics”
materials, noting a clash between their beliefs about mathematics and the ideals represented in the materials. Studies such as these illustrated the substantial role that teachers play in shaping the curriculum experienced by students.

Researchers have since examined teaching and teachers’ use of curriculum guides, seeking further insight into teacher-text relationships. Scholars who have examined the beliefs underlying teachers’ use of curriculum materials have concluded that a variety of factors tend to influence teachers’ decisions, including their knowledge of and views about mathematics (Graybeal & Stodolsky, 1987; Thompson, 1984), their perceptions of the text (Bush, 1986; Remillard, 1991; Woodward & Elliot, 1990), their perceptions of external pressures (Floden et al., 1980; Kuhs & Freeman, 1979), and their ideas about the purpose of school and the nature of learning (Donovan, 1983; Stephens, 1982).

From another perspective, researchers have argued that placing the teacher-text relationship at the center of analyses oversimplifies teachers’ curricular decisions. In a study of elementary teachers, Sosniak and Stodolsky (1993) found that teachers did not see textbooks and teachers’ guides as “blueprints” or “driving forces,” but as “props in the service of managing larger agendas” (p. 271). By capturing the role of the text in relation to teachers’ varied responsibilities, these findings suggest a need to consider teachers’ larger curricular agendas and the role the curriculum guide plays in them.

Research on what Doyle (1993) called the “curriculum process” considers teachers’ larger agendas by focusing on how they enact curriculum in their classrooms. This research focuses less on the teacher-text relationship and more on the teacher-curriculum relationship. It often includes how teachers draw on resources such as curriculum guides, but assumes that this process necessarily involves interpreting the meanings and intents of these resources (Doyle, 1993; Lemke, 1990; Snyder, Bolin & Zumwalt, 1992). Implicit in studies of teachers’ curriculum processes is a view that the enacted curriculum is more than what is captured in official policy documents or textbooks. It is the events teachers and students experience in the classroom (Clandinin & Connelly, 1992). From this perspective, studying teachers’ use of innovative curriculum resources involves trying to understand teachers’ processes of constructing the enacted curriculum and the role in it that resources play. With this in mind, our research examined the curriculum enacted by teacher educators in professional development settings and how they used the DMI curriculum in the process.
Our research questions also were influenced by recent research that examines the work of teaching in today’s reform context. As several scholars have pointed out, the current calls for reform envision a model of teaching that is significantly more complex than the traditional image of the all-knowing guide who corrects students and monitors their practice (e.g., Ball, 1997; Remillard, 1999; Simon, 1997; Steffe, 1990). Reform-inspired goals for all students that include mathematical thinking, problem solving, and communication require teachers to engage simultaneously in a number of inquiry-oriented activities. Through ongoing observation and analysis of students’ performances, teachers build models of students’ mathematical understandings and generate hypotheses regarding how their learning might progress (Simon). They take actions based on these hypotheses, but must continually modify their models and subsequent plans. In a sense, they must both direct and follow the activities of students. Simon aptly characterizes the teachers as “function[ing] within the tension among his or her current goals for student learning and commitment to respond to the mathematics of the student” (p. 80).

We assume that the work of teacher educators in this reform context is equally complex. Not only must they help teachers engage in learning about teaching that is unfamiliar and highly complex, they must take into account new ideas about how teachers are likely to learn. The DMI curriculum proposes one hypothesis about teacher learning: By examining their own and children’s understandings of mathematics, teachers will learn mathematics in new ways and rethink their teaching of it. Our aim in this research was to examine facilitators’ work supporting this sort of learning whether through use of the DMI curriculum or other means.

METHODS AND CONTEXT

To examine the work involved in supporting teachers’ learning, we used qualitative, interpretive methods to study three teachers/teacher educators using the DMI curriculum. The three teachers were among a group of approximately 10 facilitators involved in piloting the DMI materials prior to final publication. Our research represents part of the research undertaken during this pilot year. Other concurrent studies examined participating teachers’ learning and classroom practices. The three research sites varied across several dimensions, which we describe below. We selected these three facilitators to study because they were from such varied settings and represent differing backgrounds. None of the facilitators received special training in using the curriculum; however, most were involved in ongoing
conversations with the developers about its design and intent and about the processes of using the curriculum.

The Three Contexts

Marilyn, a middle school mathematics teacher, was new to teacher development work. She facilitated the DMI seminar through an agreement between her school district and a local college. She offered the seminar to elementary teachers in her district as a two-credit mathematics course while continuing to teach middle school mathematics. Four participants enrolled in the course: three veteran elementary school teachers and one middle school teacher with two years’ teaching experience. Participants met weekly for three hours over the course of the spring term.

Jennifer was a veteran teacher educator. A former elementary school teacher, she served as the curriculum specialist of her district for 13 years and sponsored and facilitated a wide range of teacher-enhancement projects. Jennifer offered the DMI seminar to a group of 30 teachers who had been meeting monthly for professional development and discussion while piloting a new elementary mathematics curriculum. The experience of teachers in this group ranged from 7 to 13 years of service. The group met once each month for six months, devoting mornings to the DMI curriculum and afternoons to the pilot project.

Connie, a mathematics teacher educator in a university setting and an experienced middle school teacher, used the DMI materials in a continuing education master’s degree course offered through her institution. The course met once a week for one semester. Drawn from school districts surrounding the university, the participants were practicing teachers with experience ranging from 1 to 30 years. A few of the participants were former students in Connie’s mathematics methods course. The seminar began with 30 students, but enrollment dwindled to 15 by the end of the semester. Connie brought to her use of the DMI materials an array of experiences facilitating professional development activities for practicing teachers.

Data Collection and Analysis

We collected data on each seminar through observations of the three-hour sessions and follow-up interviews with the facilitators, which were audio-taped and transcribed. In our observations, we paid particular attention to the facilitator’s role in orchestrating the activities of the session, her use of the curriculum resources, and the way she responded to participants’ ideas and questions. During the interviews, we asked the facilitators to give us their impressions of the session and to point out any instances that
concerned or excited them. We also asked each facilitator about specific events from the session that stood out to us as possible decision-making points and inquired into her use of the curriculum materials and her planning for the sessions. As the investigation proceeded, we became particularly interested in the facilitators’ responses to unanticipated participant comments or actions.

We analyzed the data using within-case and cross-case inductive methods of analysis (Patton, 1990). One researcher analyzed data for each facilitator with an eye toward characterizing the work involved in facilitating the curriculum. Drawing on fieldnotes, we identified the kinds of activities the facilitators engaged in before, during, and after the sessions and looked for themes across these activities. The cross-case analysis involved iterations of comparative examinations of each facilitator’s work by both researchers together, followed by additional checks with each case to confirm validity and check for disconfirming evidence. As we explored the variety of challenges the facilitators faced, we developed the theme of openings to characterize the way their work was similar. Navigating openings, as described in our analysis, was a central piece of all three facilitators’ ongoing work.

OPENINGS IN THE CURRICULUM

Despite the differences among facilitators and the seminar contexts, the three facilitators confronted unanticipated and at times awkward points in the conversations through which they had to navigate. These instances were prompted most often by participants’ questions, observations, challenges, or resistant stands on issues that were important to them. We have labeled these instances openings in the curriculum because they required facilitators to make judgments, often on-the-spot decisions, about how to guide the discourse. Here the curriculum refers to the enacted curriculum, the events teachers and students experience (Clandinin & Connelly, 1992). Initially we viewed these openings as interruptions in the natural flow of the sessions because they often felt clumsy or precarious to these first-time facilitators of DMI. Through our analysis, we came to view these breaks as potentially rich spaces in the curriculum because they presented opportunities for facilitators to foster learning by capitalizing on mathematical or pedagogical issues as they arose. As we discuss later, openings reflect tensions inherent in the type of teacher development work envisioned by the DMI creators. They are the natural consequence of interactions between what participants bring to the seminars and the kinds of learning opportunities proposed by the DMI curriculum.
In the sections that follow we describe three openings that stood out in the data. We selected these three examples because they challenged facilitators in ways that made the process of navigating through them particularly visible. Yet, the three openings discussed here are not the only types of openings we observed. As we worked to understand what openings in the curriculum involved, we began to identify openings that were more transparent than the three examples that follow. The apparent invisibility of these openings was due to the seamless way in which they were navigated by facilitators.

Searching for Pedagogical Guidance

The first type of opening we describe occurred as participants in the seminars turned conversations away from the agenda at hand and toward questions about mathematics pedagogy. Often the content of these conversations involved participants’ questions relating to a particular pedagogical approach, which, as the questions implied, they believed the facilitators advocated. These queries forged openings in the curriculum that called on the facilitator to respond.

Connie confronted this type of opening often. Participating teachers regularly sought specific advice from her about their teaching. These solicitations occurred during class sessions, but also arose as conversations “on the side.” In fact, the first instance arose early in the first meeting. In preparation for the session, participants read an assigned set of cases on child-derived algorithms for adding and subtracting two-digit numbers and brought examples of three students’ work. Connie instructed the teachers to group themselves according to the grade they taught and discuss the work samples. After moving around the room and giving the groups a few minutes to get started, Connie sat down with the five first-grade teachers and listened to their conversation.

Almost immediately Lucille, one of the teachers, began to solicit Connie’s advice about her teaching. Lucille’s face was strained and her voice determined. She explained that she showed her students how to use counters to add together two numbers. “Am I overshadowing them by showing them how to do this?” she asked, pointing to the example of student work which showed number sentences like “2 + 3” and corresponding drawings of 2 circles and 3 circles.

Connie paused for a moment and then asked several questions: “What kinds of responses have you had from your students when you give them problems like these? How many problems do you give them? How much do you let them struggle to figure out their own strategies? What kinds of strategies do you see?”
Lucille’s response was puzzled and sincere. “Don’t you have to teach them?” she asked. “We teach them the basic things and then I see them use strategies.” She reminded Connie that her students had been in first grade for just a few weeks. Connie listened and nodded as Lucille explained her concerns. Connie then looked at the other four teachers in the group, who were listening, and reminded them to be sure that everyone got a chance to share the work they had brought. She then slipped to another group. Lucille and other teachers attempted to draw Connie into similar conversations throughout the seminar (Observation, 9/10/96).

In a conversation after class, Connie referred to these interactions as moments when her “biggest fears came true” (Interview, 9/10/96). “I would sit down, they would revert away from the discussion of what they were sharing to talking about curriculum and hitting me with questions.” She found these questions frustrating because they seemed to be skeptical responses to the pedagogy in the cases or attempts to sidestep the mathematics or students’ engagement with the content.

Marilyn and Jennifer struggled with similar openings in the curriculum. Jennifer generally chose not to respond directly to questions aimed at probing her views about good pedagogy. Instead, she often waited for participants to respond, which many were inclined to do. If no one responded, Jennifer directed the group on to the next focus question, suggesting that participants postpone their inquiries and focus first on learning what they could about students’ engagement with the mathematical ideas.

In navigating openings created by participants’ pursuits of pedagogical guidance, all three facilitators resisted making specific recommendations or assertions about teaching. They did so for a variety of reasons. As a result of their own beliefs and the inquiry orientation of the curriculum, they all shared the view that it was not the facilitator’s role to promote particular approaches to teaching; they believed the facilitator should provide opportunities for participants to construct their own ideas about teaching. Connie explained, “I deliberately tried not to give advice.” When teachers persisted, she took a more explicit approach in defining her role, which she described in an interview:

I said, “You know, I want us to continue to ask this question every week, and talk deliberately about what you are thinking. If I told you what I wanted you to do, that wouldn’t really make any impact, and what I’d really like you to do is see where your beliefs and conceptions are moving to. But, I do want us to continue to talk about it each week, and I’d be happy to be a sounding board” (Interview, 9/10/96).

The facilitators’ ideas about the central purpose of the seminar also influenced their decisions to avoid responding to these questions or chal-
Challenges. Both Connie and Jennifer believed that the purpose of the DMI curriculum was to engage teachers in inquiry about mathematics and students’ thinking. Jennifer explicitly suggested that participants postpone their pedagogical questions and focus on the issues in the cases.

The facilitators also avoided challenging these solicitations for guidance – particularly the confrontational ones – because they hoped to avoid conflict. They worked hard to create a supportive and congenial atmosphere in which participants respected the views of others. Because they felt that confrontational questions or statements would threaten the atmosphere they had created, they chose to avoid them. For example, Marilyn resisted taking a pedagogical stance when challenged by a participant because she considered that her role was to help others feel comfortable in the seminar. She believed that taking a stance counter to one voiced by a participant had the potential to foster disagreement within the group, and she worried that this conflict would be counterproductive to the goal of inquiry. Thus she responded by agreeing with the participants about the preponderance of barriers to change in teaching.

This type of opening in the curriculum seemed to be motivated by participants’ searches for pedagogical suggestions and guidance. The participants enrolled in what they understood to be a professional development seminar. The seminar, however, was unlike the workshops they had attended in the past. Traditionally, teacher development activities take a how-to approach, providing teachers with a selection of activities and lessons they can use in their classrooms (Little, 1993; Sparks & Loucks-Horsley, 1990). This approach to professional development is based on “a discourse of answers” and “a confident stance of certainty” (Ball, 1997). In contrast, the DMI developers assumed that genuine and productive teacher learning should begin with inquiry into mathematics and children’s mathematical ideas (Schifter, 1998).

Taking a Prescriptive Stance

A second type of opening in the curriculum also occurred when the discourse turned toward pedagogical practices. As we noted above, participants often expressed questions or ideas about what or how they were teaching in their own classrooms. During some of these instances, other participants offered prescriptive advice. Speaking with great authority, these participants told others what to do or gave advice about what worked for them. The facilitators we studied were uncomfortable with these instances because they did not want discussions of pedagogy to be shut down by simple prescriptions.
Jennifer found herself struggling with this type of opening when a participant offered advice that had the potential to undermine the focus of a discussion of student-invented rules to compare decimal numbers. In an interview, Jennifer confided that she “hoped that participants would work on the idea that comparing the value of decimal numbers and memorizing rules were not synonymous” (Interview, 6/8/97). She believed that the case the participants had read, which described fifth graders struggling to articulate generalizations of the strategies they developed to compare decimal numbers, illustrated that, although the rules frequently taught could lead students to arrive at the correct answer, “they may not be the starting point for student learning.” At the same time she knew that most of the teachers had not thought about what it meant to understand decimal numbers.

Jennifer began the case investigation by asking participants whether the students in the case understood decimals. Several participants answered that they thought the students probably didn’t understand decimals very well or they would have been able to state a rule for determining which was larger. Another participant was unsure. She explained that she would have liked to read the students’ notebooks in order to assess their understanding. She pointed out, “But the students seemed to think that they did understand how to compare numbers smaller than one. Stating it in a rule was less important to them.”

To push the participants to examine their ideas about rules more closely, Jennifer asked them to construct the rules they might use to compare decimal numbers. As they proceeded, several participants began to voice questions about learning rules and how they related to students’ understandings of decimals. For example, one participant explained that she could see the difficulty students might have in connecting numbers such as 0.38 to the value of 38 hundredths or approximately 4/10 because the emphasis on rules led students to consider decimals digit by digit (e.g., 3 tenths and 8 hundredths). Jennifer listened with interest; the participants seemed to be circling around the issues she hoped would emerge. Then a single comment derailed the conversation. Marvin, a fifth-grade teacher, stated very directly and with authority, “I have tried lots of things, but the only thing that works with kids is having them memorize the rules, especially when they have numbers with lots of zeros.” He explained further that he had tried other approaches to teaching children to compare decimals including using manipulatives, but had success only when he showed students how to “insert the correct number of zeros and compare the numbers digit by digit.” He then challenged the group to show him another way that worked. The group grew quiet. No one responded (Observation, 6/8/97).
Afterward Jennifer expressed frustration and disappointment with this discussion. She admitted that she just didn’t know what to say. She felt that both what Marvin said and how he said it shut down the discussion and potential learning opportunities for others. She noted, “You could even feel how the atmosphere changed in the room. It seemed that even though there were probably those that disagreed, it would have been really hard to say so. I just didn’t know how or what to offer to the group or to this person. I just let it go” (Interview, 6/8/97).

Jennifer was particularly disappointed about this incident because she had carefully planned goals for the session’s explorations. She had wanted participants to explore the rules children might use to compare whole numbers and then consider whether the rules would work across the decimal point. She hoped this would prompt them to think about what understandings students might employ in comparing numbers with decimals. At the same time Jennifer confided that, since her own understanding of rational numbers was fragile, she was not sure about the answers to these questions herself. She attributed her uneasiness about how to respond to Marvin to her lack of confidence in her own understanding of decimals.

Connie faced similar openings, although none that felt so confrontational. In her sessions, some teachers – usually those with only a few years of experience – openly expressed questions or doubts they had about their teaching, and other, more experienced teachers offered specific advice. The responding teachers described approaches that worked best for them in terms of imperatives, while the younger teachers took copious notes. For example, during a discussion on place value, one teacher observed that a number of her students struggled with place value. This comment prompted a flood of suggestions and advice. Teachers described specific activities or mnemonics that worked for them. During these exchanges, Connie did not join the conversation, question the participants, paraphrase, or summarize what she heard. Although these strategies were typically part of her facilitating repertoire, she did not use them to extend these conversations. Generally she allowed these exchanges to run their course and then tried to move the group on to the next question or issue.

In Marilyn’s seminar one participant consistently challenged what he viewed as the favored pedagogical stance with claims such as these: “I would never do this in my class because I wouldn’t have time”; “My students would not respond like that”; or “We have tests to get students ready for.” These statements tended to halt the inquiry of the seminar. Marilyn appeared challenged by the comments and often responded by focusing on the comments or obstacles raised by the participant.
All three facilitators found participants’ prescriptive offerings awkward because they did not promote the kind of critique and inquiry about mathematics, teaching, or student learning that they hoped to cultivate in the seminar. Furthermore, they were concerned that by supporting comments such as these they would promote stratification within the group, implying that some participants knew more than others. At the same time the facilitators hesitated to shut down the conversations too abruptly or to challenge the specifics of the advice for fear that such moves would communicate disregard of these experienced teachers’ knowledge. So they tiptoed through these instances, neither supporting nor challenging the advice offered.

This type of opening and the opening discussed previously are similar in that both result from mismatches between what teachers have come to expect from professional development and what they encounter in the seminar. Familiar with the discourse of answers prevalent among professional development opportunities (Ball, 1997), participants expected to give advice as well as receive it. Thus it is not surprising that the discussion occasionally lapsed into exchanges of advice. In these openings, facilitators struggled to find ways of acknowledging the expertise that teachers brought with them while maintaining a stance of critique and inquiry. The facilitators were convinced that establishing a supportive and open environment was key to fostering the level of inquiry sought by the DMI curriculum, yet they were unsure about how to maintain an open environment in these circumstances.

*Invitations to Explore Mathematical Ideas*

The third opening occurred frequently for all three facilitators. This opening involved the challenges arising from exploration of mathematical ideas. The prevalence of these openings is natural since the DMI curriculum focuses on the conceptual underpinnings of the elementary mathematics curriculum. The mathematical ideas are richly complex and interrelated, and yet unfamiliar to many elementary school teachers. Most teachers learned mathematics as a set of rules to follow, not as ideas that made sense, and their understandings were fragile. Even those who felt familiar with the mathematics found themselves seeing new relationships and patterns. The explorations they engaged in took participating teachers onto new mathematical ground. As a result, teachers frequently expressed surprise, inspiration, insight, confusion, frustration, and curiosity in their encounters with the mathematical ideas that undergird the facts and procedures they had once memorized. Faced with these reactions, the facilitators needed to decide how to respond. At times the facilitators
themselves proceeded into new mathematical terrain even as they faced these decisions. In the following example, Marilyn’s decision to push participants to examine a mathematical relationship more deeply was prompted by both new conceptual insights she gained and changes in her view of the facilitator’s role.

During an activity focusing on two-digit multiplication, Marilyn asked her group to create representations of $16 \times 18$ with diagrams using base-ten materials. As Marilyn worked on the problem, she began to notice a mathematical connection she had never made before. In a somewhat surprised tone, she exclaimed to the others, “Multiplying two-digit numbers in the form of an array looks a whole lot like multiplying binomial factors $(x + a)(x + b)$. This is the first time I have actually put multiplication and algebra together.” The room fell silent for a few moments, after which Marilyn commented:

You know, it seems that somehow, somewhere along the way, I have overlooked the idea that simple two-digit multiplication underlies the more complicated idea of binomial expansion. It occurs to me now that I have been working with middle school children for all these years and never really made that connection.

The participants in the group stopped to listen to Marilyn. She continued, “It may have been useful to have students use arrays to multiply two-digit numbers in eighth grade and then draw on this experience to learn about multiplying binomials.”
While talking to the group about her insights, Marilyn studied their faces to assess whether they saw the same connection and whether it was important to them. She asked, “Is anyone else seeing this?” No one acknowledged that they were. Marilyn hesitated for a moment and then began to show the other participants her diagram and explain the connection she had made. She illustrated the rectangular array she had constructed for multiplying $16 \times 18$ and beside it another array illustrating the multiplication of $(x + 6)(x + 8)$. After several minutes of explanation the participants remained puzzled.

As Marilyn pressed on, several related questions and observations arose from the group. Looking carefully at Marilyn’s drawing of $16 \times 18$, one participant noticed that the arrangement of rods represented the partial products of the conventional multiplication algorithm. The drawing included a $10 \times 10$ square representing 100, a set of 6 and a set of 8 long rods representing 6 tens and 8 tens, and 48 small squares representing 48. Other participants’ questions focused on the associative and distributive properties. As Marilyn waited and watched the conversation evolve, she seemed pleased that participants were asking questions, but decided not to push the relationship to algebra any further (Observation, 4/15/97).

In an interview that followed, Marilyn explained her decision to open the discussion about what she noticed. “I really saw for the first time why kids have so much trouble understanding algebra. In that moment I knew that I had taken my own understanding of algebra for granted. I wanted others to see this.” This inspiration, however, was not her only reason. She was also reassessing her role as facilitator. She explained, “In the beginning of the seminar, I relied on the materials to stimulate the conversations. I saw my role as the organizer. I also wanted to make everyone comfortable. But, over time, my views began to change.” Marilyn explained that she began to realize that “in walking the cake walk where you try to be so careful that no one’s feelings get hurt, the agenda often got lost. Really, nothing got challenged, no one was willing to risk putting themselves out there” (Interview, 4/15/97).

For Marilyn, this new perspective on her role as facilitator represented a significant shift. Earlier in the seminar she was less likely to initiate a discussion about a complex mathematical idea. Instead, she avoided pressing participants to explore mathematical ideas so that no one would feel put on the spot or forced to risk revealing what they did not understand. Over time, Marilyn had grown increasingly dissatisfied with the conversations in the seminar. Inspired by the mathematical connection she made, she saw an opening that she thought was worth the risk and decided to push participants in that direction. Although she knew that participants
did not fully grasp the connection she made, she thought the discussion was significantly more ambitious than those the group had earlier in the seminar. She was impressed with both the observations participants made and the connections they drew between the base-ten model and the partial products of the multiplication algorithm. “In the case of one participant,” Marilyn speculated, “I think this may have been the first time to ever see a physical model of the traditional [multiplication] algorithm” (Interview, 4/15/97).

Each facilitator we observed confronted questions about whether and how to support participants’ mathematical explorations and learning. In many of these instances, the facilitator made the decision to pursue the particular mathematical idea, as Marilyn did. Connie was particularly inclined to follow up on mathematical questions and observations that arose. Jennifer tended to probe many of the mathematical discussions with general statements, such as “I know there is something more to this” and “Let’s keep looking.”

We also observed a number of instances in which the facilitators chose not to follow mathematical leads. Connie made that choice during a discussion of children’s work with base-ten materials. Several participants raised questions about students’ understanding of place value and the role played by the study of other bases. In response, other participants offered observations and perspectives about the base-ten system with little or no evidence to support their claims. Some of the claims seemed to be based on partial knowledge. For example, one teacher claimed that base 10 was chosen for the conventional system because of the patterns inherent in a system based on 10. Connie listened and nodded. At that moment she did not interject specific questions or challenges, and the conversation moved swiftly to a new issue (Observation, 9/24/96).

Later Connie described her thoughts during this discussion. She noted that the conversation was moving quickly, which made interjecting difficult. She recalled being troubled by many of the assumptions reflected in participants’ comments, explaining, “I thought, ‘They have so many varied ideas of what base 10 is.’ ” She offered two reasons for not pursuing that issue at that moment: “I didn’t have a ready-available task to pose to them, nor did I think that was the place to do that. It wouldn’t have helped me in the goals I had for the class.” She explained that in other situations she might have provided a task in a later session to encourage participants to examine their ideas about place value. She knew she would not do this, however, because she wanted to follow the agenda offered in the curriculum. Given the focus of the curriculum, she was confident that the same questions would reemerge and “We can say, remember this
conversation.” While Connie seemed comfortable with the decision she had made during the session, she also recalled feeling uncertain about it in the moment (Interview, 9/24/96).

Similar invitations to explore mathematical ideas emerged frequently in the seminars and all three facilitators struggled with whether and how to respond. In some instances the facilitator backed off completely to avoid putting participants on the spot. At other times she chose to move forward with the agenda of the curriculum rather than pursue an emerging mathematical issue. Still, at other times, the facilitator chose to veer from the plans to explore the particular idea.

THE TENSIONS UNDERLYING THE OPENINGS

Our examination of the openings just described revealed that a set of tensions underlay the discourse in the professional development sessions and that these tensions often figured into the facilitators’ decision making. We do not view these tensions as “problems” that were avoidable or easy to fix. Instead, they are similar to the dilemmas of teaching identified by Lampert (1985). She argues that because the work of teaching involves attending to multiple, often competing agendas, teachers constantly confront dilemmas of practice. The work of teaching involves managing these dilemmas, rather than seeking to eliminate them. As we describe below, the tensions DMI facilitators faced involved competing goals, expectations, and approaches to teaching that facilitators need to navigate. Examining these tensions can provide insights into the work of facilitating teacher learning.

The first opening involved participants’ assumptions that facilitators advocated a particular approach to teaching mathematics. Although each facilitator responded to questions and challenges differently, all three wrestled with tensions between what participants wanted from professional development and the assumptions underlying the curriculum. In the second opening, we identified the tendency for participants to insert prescriptive advice about how to teach. The tension facilitators faced in these instances between the participants’ images of professional learning and that envisioned in the curriculum is similar to those in the first opening. As Ball (1997) reminds us, the professional development that most teachers are familiar with focuses on solutions and answers. A second tension associated with this opening was between the facilitators’ desires to maintain a stance of inquiry in the seminars and at the same time create a safe environment in which all participants’ ideas were valued and welcomed. This tension is parallel to Simon’s (1997) characterization of
tensions faced by teachers of mathematics who must take their lead from students, but work toward particular mathematical goals. Wilson and Berne (1999) remind us that maintaining this balance in professional development settings is particularly challenging, since inquiry and subjecting one’s practice to examination are risky for teachers.

In the third opening, we describe the multiple and varied opportunities that arose in each session around explorations of mathematical ideas. In openings of this type, facilitators had to decide what they thought was important mathematically for participants to explore or learn, how they might invite participants to do so, how much to push the explorations, and whether the timing seemed right. In some cases, facilitators were exploring the particular mathematical ideas themselves for the first time. One tension, in this case, was between mathematical goals and the immediate interests or questions of the participants. Another was between the designed trajectory of the curriculum and the opportunities offered in the immediate moment of the seminar.

NAVIGATING OPENINGS IN THE CURRICULUM TO SUPPORT TEACHERS’ PROFESSIONAL LEARNING

A close look at the three openings and the tensions that underlie them reveals conflicts between and within the goals and commitments of the facilitators, the expectations of the participants, and the agenda of the DMI curriculum. Our analysis of the openings sheds light on the questions guiding this study: What is involved in using an innovative teacher development curriculum and supporting the kinds of teacher learning compatible with current reforms in mathematics education? We see openings, because they signal places of conflict or discontinuity between the goals of participants and the facilitator or the curriculum, as holding significant potential for inquiry and learning. Often initiated by the concerns and observations of participants, including the facilitator, these openings invite opportunities for facilitators to structure conversations and explorations that can extend or challenge participants’ knowledge and beliefs. Our analysis of the three facilitators’ efforts to navigate openings in this study illuminates the nature of the work of supporting teacher learning.

While the idea of openings in the curriculum grew out of our analysis of facilitators using the DMI curriculum, it is reasonable to suggest that all teacher educators engaging teachers in reexamining mathematics teaching and learning are likely to confront similar openings – unanticipated and at times awkward points in the conversations – through which they had to navigate. Thus, the following discussion of the work involved in navigating
openings has relevance to the work of teacher educators in general who seek to support reform in mathematics education through fostering teacher learning. Later we discuss issues directly related to the use of innovative curricula.

Our observations revealed that facilitators’ responses to openings varied tremendously. On some occasions their responses seemed spontaneous, even automatic. At other times facilitators seemed entirely cognizant of the competing goals at play and of the trade-offs that a particular decision was likely to entail. Regardless of the extent to which the facilitators’ decisions were explicit or tacit, we found that all three facilitators engaged in a set of three activities central to the navigating process: (a) reading the participants and the discourse, (b) considering responses and possible consequences, and (c) taking responsive action. This cycle of activities, which includes analysis and consideration of goals and taking action, is similar to a model proposed by Remillard (1999) of the teacher’s role in shaping the enacted curriculum. Similar to Remillard’s findings, we found that this process was not linear, but fluid and interactive, often appearing to be spontaneous. In the following sections, we draw on our earlier examples of openings to illustrate these activities.

Reading Participants and the Discourse

Throughout the openings we saw examples of facilitators reading both participants and the discourse, to take stock of the general group, and individual participants’ understandings, interests, intentions, and comfort levels. For example, when the teacher in Connie’s seminar asked her for advice about teaching students computational strategies, Connie responded by asking a series of questions to learn more about the teacher’s views and approaches. Similarly, when a participant in Jennifer’s seminar interjected an imperative related to teaching decimals, Jennifer noted the authority with which he spoke and the awkward silence that fell over the group. Marilyn also read participants in her seminar as they explored the array model of two-digit multiplication. She listened to them discuss the model, assessing the insights they were gaining.

Reading both individual students and the class as a whole is viewed as a critical component of teaching (Remillard, 1999; Ball, 1997; Sullivan, 2000). Such reading in reform-oriented professional development settings involves reading more than the learners’ understanding of the content. It also involves assessing participants’ willingness to learn in nonconventional ways.
Considering Responses and Possible Consequences

As facilitators read participants and the discourse, they considered possible responses the participants might make with respect to their goals for the seminar. Sometimes this process was tacit occurring rapidly. Reminiscent of Lampert’s (1985) dilemmas of teaching, the goals against which the facilitators weighed options were multiple and sometimes conflicted with one another. For example, in considering whether to question Marvin’s pedagogical claim, Jennifer weighed several goals. She believed that neither the content of his advice nor the way in which he stated it supported her goal of promoting an inquiry-oriented stance toward learning. On the other hand, she was concerned that challenging Marvin would fly in the face of another goal – creating a safe and congenial environment for learning. Similarly, when considering how to respond to participants’ pedagogical challenges and questions, each facilitator weighed the goal of supporting and acknowledging participants’ developing insights about teaching against the goal of encouraging inquiry into mathematical ideas.

In several instances the process of weighing responses against competing goals involved balancing mathematical goals against the curriculum agenda. This was the case for Connie when she considered whether to pursue claims that participants made about place value or to stick with the suggested plans offered in the curriculum. She believed that mathematical questions were a productive way to encourage teachers to examine their assumptions; but she also valued the insights of the curriculum developers and felt reluctant to move the conversation too far off track. Understanding that unpacking the structure of the number system was an underlying goal of the complete module, she was confident that the issues raised in the moment would reemerge, so she chose not to pursue the topic of place value at that time. Yinger (1988) referred to the kind of deliberation teachers do in the midst of teaching as a “three-way conversation between teachers, students, and the problem” (p. 86). He used the term “problem” to refer to the actual task being taken up by the teacher and students. Our analysis suggests that in many cases the conversation might include a fourth member – the curriculum guide. Considering how to respond involved all three facilitators in weighing the interests of these four constituencies.

Taking Responsive Action

Through the process of considering responses and goals, the facilitators decided how to respond to the opening. Sometimes their actions favored one goal over another. When Jennifer decided not to respond to Marvin’s pedagogical interjection in order to keep the discourse smooth, she was
choosing what she believed would foster a safe learning environment. At other times facilitator actions reflected attempts to navigate two or more conflicting goals. Connie’s response to teachers who continually asked for pedagogical advice exemplifies this approach. In deciding to explain her perspective on pedagogical development, and by agreeing to act as a sounding board in these conversations, Connie acknowledged participants’ yearning for pedagogical advice while maintaining her commitment to prioritizing mathematical explorations.

The responsive actions described here are similar to what Gay (1995) identified as “considered” action. According to Gay, considered actions are based on self-reflection and analysis and are open to ongoing adjustment. The extent to which the facilitators’ actions were deliberate varied across the three facilitators and changed over time. As we argue below, awareness of the navigational process is critical to the work of supporting teachers’ professional development.

**Awareness of the Navigational Process**

Looking comparatively at the three facilitators, we found that the more options and possible consequences facilitators were able to consider in light of competing goals, the more likely they were to take deliberate action. Connie, who had experience working with practicing teachers around reform-related ideas, brought to her use of the curriculum a repertoire of options she might take in responding to the teachers’ questions and concerns. She also had a deeper understanding than the other two facilitators of the mathematical and pedagogical goals of the DMI curriculum. This knowledge and experience supported her in navigating openings and taking on the tensions they represented. In Marilyn, we also saw differences over time in the choices she made regarding how hard to press participants to examine mathematical ideas; these differences seemed to indicate she had gained knowledge of possible consequences of her choices. Initially Marilyn tended to avoid these opportunities. She expected that the curriculum itself would support participants’ mathematics learning. Her primary concern was to create a safe learning environment for the participants. Over time, as her understanding of competing goals increased, she recognized that the seminar contained limited opportunities for deep mathematical learning. She began to weigh her concerns for a comfortable learning environment against the goal of extending mathematical learning opportunities. Her choice to encourage participants to explore the mathematics reflected both her growing understanding of the goal to foster mathematical learning and her sense that a comfortable learning environment may involve risk taking.
We believe that as facilitators gain experience working with curriculum like DMI, they are increasingly likely to recognize places where openings in the curriculum may occur. Marilyn, for example, represents a case of a facilitator whose tendency to recognize and deliberately navigate openings increased with her use of the curriculum. Initially she viewed her role as primarily organizational. As the sessions proceeded, she began to take a more deliberate stance in facilitating participants’ learning. Through gaining awareness of openings and competing goals associated with them, facilitators may become more likely to take explicit action in response to openings in the curriculum. The relationship between navigating openings and growth in facilitators’ awareness of this process is reminiscent of Remillard’s (1996) observation regarding teacher learning and curriculum use:

The most fruitful sites for learning occurred when the teachers had to read the text, their students, or situations in their teaching with an eye toward designing or constructing curriculum. This process of reading and decision making caused the teachers to reexamine their beliefs and understandings that, in turn, influenced the curriculum they enacted (p. 256).

Reconsidering Curriculum Resources

The view of openings we propose has implications for how scholars and practitioners think about the role of curriculum material in the work of teachers and teacher educators. We believe that well-navigated openings allow facilitators to take deliberate action to foster the kind of learning intended by DMI developers even when doing so involves “veering” from the plans suggested in the curriculum. In a sense, openings may be signals that the curriculum is working.

This stance assumes a novel perspective on curriculum materials and their use that is critical to the successful implementation of reform-inspired programs. Traditional views of curriculum materials hold that they are fixed guides to be either followed or veered from. A view of curriculum use as embracing and exploiting openings, as we propose, assumes an interactive relationship between written and enacted curriculum. As Lloyd (1999) suggests, “Curriculum implementation consists of a dynamic relation between teachers and particular curricular features” (p. 244). In other words, implementing an inquiry-oriented curriculum demands that facilitators/teachers take advantage of openings as they emerge and that these openings are likely to vary from context to context.

This view of the role of curriculum resources is also different from that suggested by Sosniak and Stodolsky (1993) who argued that teachers view curriculum materials as “props in the service of managing larger
agendas” (p. 271). We believe that well-designed curriculum resources can contribute to teachers’ or facilitators’ larger agendas without constraining them. It is our view that learning to use innovative curriculum resources includes learning to assume an interactive relationship with these materials and their developers. Implicit in this view is the assumption that curriculum developers redefine their role in guiding the work of teachers and teacher educators.

CONCLUSION

In this final section, we consider what our analytic frame of openings in the curriculum suggests for improving professional learning opportunities for teachers of mathematics. Our analysis highlighted the critical role teacher educators play in fostering inquiry and exploration within teachers’ professional learning opportunities regardless of whether curriculum materials are involved. It follows that assisting teacher educators in learning to navigate openings can contribute substantially to learning opportunities for teachers. We suggest that productive learning opportunities for facilitators must help them learn to (a) recognize openings, (b) identify and unpack the tensions that underlie them, and (c) understand processes of navigating them. We examine each of these suggestions and speculate about how this learning could support teacher educators.3

We identified openings initially by focusing on places in the curriculum that seemed difficult or uncomfortable for facilitators or participants. Through our analysis we came to view openings as opportunities for facilitators to pursue critical learning goals. Facilitators of professional development would benefit from learning to recognize and expect openings in the curriculum and frame them as points where participants’ learning can be supported. Such a view of openings would cast a different light on the facilitator’s role. Although facilitators may continue to find openings difficult to navigate, they would recognize them as the natural consequences of how participants engage with a curriculum intended to support reform in mathematics education. In short, openings could be understood as an indication that a curriculum is working because they reveal places where some of the most critical and deliberative work of the facilitator can occur. Still, we do not see teacher learning as a straightforward and uncomplicated process.

To support participants’ learning within openings, facilitators would need to learn to unpack them. We argued earlier that each opening involved tensions among competing goals. Further, we saw important differences in each facilitator’s awareness and understanding of these tensions. We
believe that facilitators need to learn to uncover and understand the tensions underlying openings. At the same time they need to have opportunities to examine their own goals and learn about the goals of the curriculum. This learning would involve coming to understand the range of tensions at play in any one opening. It would also involve helping facilitators expand their repertoires of responses within an opening. We observed, for example, the change in options available to Marilyn as she began to consider a wider array of alternative goals. As a result, she deliberately chose to push participants to explore mathematical ideas more deeply. We can speculate that, through learning to recognize and unpack competing goals underlying openings, Marilyn would be increasingly likely to take deliberate action to foster the learning agendas of the curriculum.

As facilitators learn to unpack openings, they also need to consider possible consequences of actions they might take. This learning, we speculate, would promote a clearer sense of the connections between facilitators’ decisions and participants’ learning. This understanding is perhaps the most critical of the navigational process. A facilitator’s choosing, for example, to act as a sounding board in conversations that move quickly away from mathematical learning and into pedagogical approaches has different consequences for participant learning than a facilitator’s asking participants to refocus their conversation on the mathematics. We are not suggesting that one approach is preferable. Instead, we argue that each approach has consequences for the interaction and how it develops, as well as for what and how participants learn. We believe that, as they learn to examine various responses in light of possible consequences, facilitators will grow increasingly aware of the range of navigational choices available to them and of the connection between those choices and what participants may be learning over time. This awareness likely will result in facilitators taking increasingly deliberate stances to foster learning that the curriculum was designed to initiate.

It is important to recognize that relationships between facilitators’ choices, or any professional development activity, and what teachers learn are not well established. In fact, as Wilson and Berne (1999) point out in their review of contemporary professional development, “The ‘what’ of teacher learning needs to be identified, conceptualized, and assessed” (p. 203). We concur that the field would benefit from more clarity on what teachers learn from inquiry-oriented professional development. Findings from such research would inform the work of facilitators as they consider the possible consequences and aims of their pedagogical choices.
Earlier we claimed that in some instances facilitators began to recognize openings in the curriculum and considered various ways to navigate them. However, we argue that relying on experience alone to foster facilitators’ abilities to identify openings and to use them deliberately to promote participant learning leaves to chance much of what is needed to support teachers’ professional learning. The need for classroom teachers to receive professional support when using new curriculum materials or experimenting with new practices is well established (Remillard, 1996; Ball, 1997; Cohen & Barnes, 1993; Heaton, 2000; Lloyd, 1999). Teacher educators using an innovative curriculum for teachers require similar support. Just as facilitators need to take deliberate action to support participants’ learning, those supporting facilitators must intentionally structure opportunities for facilitators to learn to recognize, unpack, and navigate openings in the curriculum.

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NOTES

1 By using the DMI curriculum with teachers, the three participants were taking on the role of teacher educator regardless of their formal titles (teacher educator, teacher, curriculum specialist). For clarity, we use the term facilitator to refer to the three participants working with the curriculum because it is the term used by the DMI developers. However, when referring to the work of supporting teachers or guiding teacher learning more generally, we use the term teacher educator.

2 The facilitators’ names are pseudonyms.

3 The developers of the DMI curriculum have continued to examine this issue. Besides a journal written by a fictitious facilitator in the materials to support facilitators’ thinking, they offer a teacher educator institute and an electronic discussion forum for facilitators using the curriculum. These forms of support provide additional sites for future research.

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