# Standards-Based Mathematics Assessment in Middle School

## Rethinking Classroom Practice

THOMAS A. ROMBERG
EDITOR

TEACHERS COLLEGE PRESS

Teachers College, Columbia University
New York and London

Chapter 10

# Enriching Assessment Opportunities Through Classroom Discourse

David C. Webb
University of Wisconsin–Madison

In spite of the critical role of instructionally embedded assessment in the teaching–learning process, studies that document teachers' classroom assessment practices have offered little evidence about the ways that teachers use assessment to inform instruction. Teachers accustomed to assessing student learning of skill-oriented mathematics curricula often struggle with interactive assessment practices to inform instructional goals aligned with reform mathematics curricula. So that teachers can recognize and take greater ownership of classroom assessment practices that support instructional decision making, case studies of the ways in which teachers use classroom discourse to support student learning and guide instruction are needed.

## DISCOURSE-BASED ASSESSMENT PROCESSES

Gathering evidence and providing feedback are two assessment processes that often are embedded in classroom discourse. When teachers prompt students to share, explain, and justify their problem solutions, teachers provide all students with an array of mathematical representations against which they can contrast their own conceptions. Verbal feedback (from either the teacher or the students) can be seamlessly integrated into the flow of instruction when teachers place a priority on sense making, explanation, and justification.

Teachers regularly gather evidence to assess students' prior knowledge, level of engagement, interpretation of tasks, and disposition toward mathematics. Whereas classroom discussions present an ideal opportunity to explore student understandings and inform instructional decisions, waiting until the next quiz or chapter test yields information too late. Assessment of students' conceptions therefore is best accomplished at the site where student learning develops, through classroom discourse in which the teacher can simultaneously monitor student interpretations of the task, solicit additional information from students, and communicate expectations for mathematically valid representations. The medium of classroom discourse provides a supportive context for students to share partial understanding and misconceptions, and instructionally embedded assessment allows teachers to gather information about students' partial understanding or misconceptions and to further investigate students' intended meaning through additional probing, guiding, and reframing of questions.

Mathematically substantive feedback provides students with contrasting information to improve their responses to mathematical tasks and their articulation of mathematical principles. Feedback can be oral or written, formal or informal, private or public, geared toward an individual or a group (National Council of Teachers of Mathematics, 1995). Feedback can be directed to frame initial reactions to an unfamiliar problem, highlight changes in student conceptions over time, and juxtapose current performance with hoped-for performance (Wiggins, 1993). Feedback can be withheld (e.g., continued observation of student progress), offered indirectly (e.g., eliciting responses from other students), or provided as a direct response to one or more students.

Students receive feedback from a variety of sources, including verbal feedback from teachers and peers, that provide a coherent portrait of classroom norms and expectations. Classroom discourse can be used to provide confirming and relational feedback from several directions, giving students the opportunity to share and critique the explanations, arguments, strategies, and responses of other students. The ongoing use of classroom discourse as a source of feedback also promotes assessment of students' own and one another's work. Black and Wiliam (1998) argue that self-assessment cannot be treated as "an interesting option or luxury; it has to be seen as essential" (p. 21). Ideally, classroom assessment practices should contribute to students' internalization of performance criteria so that students can negotiate teacher expectations and engage in meaningful self-assessment. To accomplish this requires an instructional environment in which performance criteria are open, students have opportunities for reflection, and student self-assessment is modeled and valued.

## CASE STUDY OF DISCOURSE-BASED ASSESSMENT: MS. KOSTER

The following case study of one teacher's discourse-based assessment practices is part of a series of studies conducted by the Research in Assessment Practices (RAP) study group. (For more details of this case study, see Webb, 2001.) The instructional goals and practices of teachers selected for this particular study were aligned with the assumptions regarding how classrooms promote learning for understanding (Carpenter & Lehrer, 1999). Because these learning objectives require greater use of written and verbal language, teachers needed to complement their use of time-restricted, paper-and-pencil quizzes and tests with more discourse-based assessment techniques. Overall, teachers recognized classroom discourse as a critical aspect of their assessment practice.

The primary research question guiding this study was, What assessment practices do mathematics teachers in the middle grades use during instruction to gather evidence of student learning? Data sources were selected to provide a record of verbal and visual teacher–student interactions and to record teachers' conceptions of and struggles with discourse-based assessment practices. Teacher interviews, classroom observations, and video recordings were used to develop a record of teacher–student communication and to chronicle how teachers utilized the instructional activities in each unit of *Mathematics in Context* (MiC; National Center for Research in Mathematical Sciences Education & Freudenthal Institute, 1997–1998). Three semistructured interviews (each approximately 60 minutes long) were administered according to a protocol developed to follow assessment-related constructs that emerged during classroom observations: one interview prior to the 6-week period, a second interview after 3 weeks, and a third interview at the conclusion of the 6-week period. Teachers' discourse-based assessment practices were documented through daily observations and videotape of each lesson. Using audio equipment, we were able to record whole-class, group, and individual teacher–student interactions. Classroom observations and field notes focused specifically on teacher–student interactions that potentially could be used for assessment purposes.

Ms. Koster was selected for in-depth study as the result of discussions with Design Collaborative researchers who noted her use of classroom discourse in observation reports and described her instructional practice as a rich source of evidence for investigating discourse-based assessment. Data gathering for this case study was initiated while Ms. Koster was using several algebra units from MiC. Ms. Koster had been teaching elementary and middle school students for over 20 years and, at the time of this study, had a seventh-grade mathematics and language arts teaching assignment. The classroom in which this study took place was characterized as an "accelerated" seventh-grade class. Ms. Koster was an experienced teacher whose love for language was evident in the way she presented mathematics to her students. She used mathematics as an opportunity for students to engage in logical reasoning and use precise, specialized vocabulary. The use of realistic contexts and language in MiC supported her underlying instructional goal, which was to demonstrate to students that the study of mathematics involves more than just finding a correct answer. Beyond routine procedures and problem solving, mathematics also involves appropriate use of language (i.e., communicating of mathematical principles, explaining solution strategies, and justifying the validity of proposed methods). As she explained, "I can't teach anything without the importance of language—to use the right words for the right spot. Or if you don't know [the words], at least a verbal flexibility to try and explain what you want to get across" (Koster, interview, May 6, 1999).

In Ms. Koster's class, the spoken word was used as the primary medium to communicate mathematical thought, and "depth of thought" was established as the goal for students to strive toward when sharing an explanation. Ms. Koster felt that she gained the most reliable information about student understanding through her interactions with students. She viewed the context of instruction as an effective forum for communicating her expectations and for providing guidance and feedback on student responses to problems. Ms. Koster's comfort with and dependence on students' verbal responses influenced how she selected and used tasks with MiC and led her to take an instructional stance where she could quickly adapt lessons according to students' prior knowledge and degree of interest. Ms. Koster demonstrated a strong ethos of respect for her students and honored her students' unique talents and idiosyncrasies. When asked to describe her conceptions of assessment, she replied, "It goes to the heart of respect and caring. It's not our job to get 'em and point out that we got it and you don't" (Koster, interview, May 6, 1999). Rather than using assessment as a means to highlight students' shortcomings, Ms. Koster portrayed projects, presentations, and written tests as "opportunities for students to showcase their learning." Her understanding of the various ways in which students learn mathematics motivated her to adopt a broad view of classroom assessment and to develop methods to elicit representations of student learning that were more authentic.

## PRINCIPLES AND PRACTICES OF DISCOURSE-BASED ASSESSMENT

Ms. Koster viewed student engagement as an essential aspect of instruction and assessment. To motivate student engagement with the problem context, Ms. Koster argued that she had to first "hook the students" and reel them into a problem situation. Capturing and maintaining student interest was an important instructional goal reflected in many of Ms. Koster's lessons, and these instructional hooks allowed her to promote and sustain classroom discussions, which she then could use to assess student learning. During the beginning lessons, Ms. Koster often asked students a series of unexpected questions that were laced with humor and creativity. As an example, for the growth charts problem in the MiC unit, Ups and Downs (Abels, de Jong, et al., 1998, pp. 14–16), in which students are asked to graph and interpret growth charts for young children, the text included a photograph of an infant being weighed on a doctor's scale. Ms. Koster decided to introduce this problem context as follows.

[Ms. Koster is in the front of the class, facing the students who are seated in groups of three to four. Ms. Koster has just turned to page 14 of the teacher guide. (Time stamps for the videotape are noted in the left margin.)]

13:55 *Teacher:* Cute baby on page 14! [Students in unison, "Awww."]

14:05 *Teacher:* Please turn to 14. [Waits for students to quiet down.]

14:22 *Teacher:* Look at the baby. Roger, name the baby.
*Roger:* Wow! Name the baby?
*Teacher:* Sure, name the baby.
*Roger:* Brian.

*Teacher:* This is Brian?—Julie, name the baby.
*Julie:* Ah—ah—Judy.
*Teacher:* Judy! [Laughs.] We had a discussion about this name earlier this morning. Name the baby.
*Oliver:* Habib.
*Teacher:* Charles, name the baby.
*Charles:* Bob.
*Teacher:* Bob, the baby. Alysha, name the baby.
*Alysha:* Rover.
15:26 *Teacher:* Rover? [Students laugh.] Hector, why bother?
*Hector:* What?
*Teacher:* Why bother? Why fool around with naming the baby?
*Russ:* 'Cause it's fun.
*Teacher:* Yeah, 'cause it's fun.
*Christina:* Because when it gets older you can't just call it "It."
*Teacher:* Okay. Backup. Rewind. Look at page 14. It's a whole page of statistics—research and statistics. And if you are not careful, what happens when you research and write down statistics? You lose all connection to the fact that what you are really trying to understand is a human. We want to know if this baby is thriving. We want to know if this baby is growing and developing the way it is supposed to. So perhaps if I suggest to you, fool around and think of the baby as a human rather than as a chart full of statistics, those of you who go into research and read charts full of statistics stuff will remember to keep your humanity with you. So, look at the chart full of statistics. This baby is weighed how often?
(Koster, video transcript, March 10, 1999)

Along with other techniques that Ms. Koster often embedded in her lessons, this excerpt demonstrates how she used instructional technique and light humor to capture her students' attention. As you may have noticed, this interaction includes no discussion of mathematics content. Rather, Ms. Koster used the problem context to evoke student interest and establish a purpose for what her students were about to do. This use of contextual, instructional hooks is a pattern of practice that was noted in at least one third of the observed lessons. During an interview that took place 3 weeks into the unit, Ms. Koster elaborated on this instructional goal.

> It is my style, so I don't know that I consciously think of this, but I need to convince them that this is worth thinking about. I need a hook. I need to tell them I ran a marathon. I need to say, "Hey buddy, I want to rent a motorcycle." I think through how I am going to hook them. "We gotta give a name to this baby before we can measure this baby." That, to me, is the big deal. Reel them in a little bit. (Koster, interview, March 26, 1999)

Ms. Koster argued that to motivate student engagement with the problem context, she had to first "hook the students" and reel them into the situation. Capturing and maintaining students' attention was an important goal reflected in many of her lessons. Ms. Koster's attention to student engagement promoted and sustained classroom discussions, which then could be used to assess student understanding. Clearly, Ms. Koster understood student engagement to be a prerequisite for discourse-based assessment.

### Discourse-Based Assessment Techniques

Analyses of videotape and field notes revealed three distinct patterns of discourse-based assessment that elicited qualitatively different student responses and provided unique opportunities for instructional assessment: (1) "temperature taking," (2) funneling responses, and (3) probing assessment.

A majority of the observed discourse-based assessment opportunities represented what Ms. Koster later called *temperature taking*. When asked to characterize how she assessed student learning, Ms. Koster remarked:

> I am not big on calling a question and waiting for waving hands in the air, and so you will see me use a stack that has their names on them. My attempt is to call on every kid once a day. To at least hear them say, "I don't know" or "I get it" or "Could you explain it again?" or "246"—whatever it is. That is the temperature taking. I walk around and look over shoulders (Koster, interview, March 2, 1999).

During whole-class discussion, Ms. Koster asked temperature-taking questions at a brisk pace, offering little or no feedback. Her instructional stance during temperature taking was strictly to solicit information and, instead of offering feedback, ask students to judge the validity of their responses. After eliciting a response, Ms. Koster either asked different students the same question or moved on to a new problem.

This technique included choral responses, visual gestures, and instances in which Ms. Koster asked the same (or closely related) questions to several students. Even though temperature taking provided only superficial evidence of student learning, according to Ms. Koster it was a fundamental process for making instructional decisions.

With the *funneling responses* technique, Ms. Koster used a series of questions or statements to lead students to a particular response. She used hints, suggestions, and sequential questioning to elicit the "correct response." With this approach, Ms. Koster often used student responses to emphasize a specific procedure, make a point, or instruct. The manner of closed questioning used with this technique restricted the range of student responses, which resulted in limited representations of student knowledge. Student responses were used to display and reinforce information rather than reveal alternative representations or solutions.

With the *probing assessment* technique, additional questions or statements were used to probe the meaning of students' initial responses. Observers identified three variations on this probing technique.

- *Restate*. Prompt students to restate their response in a different way or clarify their response.
- *Elaborate*. Prompt students to share their interpretation of a problem, often by explaining a strategy or justifying the validity of a solution strategy.
- *Inquiry*. Use counterexamples, another interpretation, or alternative representations to shift teacher–student interaction to the sustained inquiry of a problem context or concept. Often, new questions were used to prompt the deliberation of previously elicited student (mis)conceptions.

Whereas temperature taking helped Ms. Koster sustain student engagement and informed her choice of appropriate follow-up questions, probing assessment revealed more substantive representations of student knowledge. Using relational questions, Ms. Koster was able to assess the extent of students' conceptual connections. Answers elicited without elaboration indicated the potential for student understanding but did not provide substantive evidence to assess the meaning of a student's response.

The reactions and responses of the students during temperature-taking activities often were used as a basis for instructional adjustments. When student engagement was in short supply, Ms. Koster would ask new questions, draw a different representation, make connections to a novel students had read (in language arts), or share an experience from her childhood. When student engagement was sufficient, temperature taking was used to reveal opportunities for further instruction or additional probing of student responses. These instructional decisions were based largely on intuition or interest in exploring a student response.

> So much of it is a gut level. It's, "Okay, you got it!" And some of it is, "Is this you struggling or is this everyone struggling?" And some of it is, "That's a good thought. Let's go even further. Let's make it a bigger world." (Koster, interview, March 2, 1999)

In many cases of temperature taking, multiple answers for the same question were solicited from a random sample of students. The following excerpt from Ms. Koster's classroom details the style of teacher–student interaction that was observed during these episodes and highlights the type of student responses that preceded a shift to other discourse-based assessment techniques:

[In Ups and Downs (Abels, de Jong, et al., 1998), students read about the accomplishments of Joan Benoit, who won the women's marathon in the 1984 Olympics in a time of 2 hours, 24 minutes, and 52 seconds (p. 29). On the next page, students are told that a marathon runner "will lose about 1/5 liter of water every 10 minutes." Problem 5 asks students, "How much water do you think Joan Benoit lost during the women's marathon of the 1984 Olympics?" Ms. Koster begins asking students questions from the front of the classroom.]

17:15 *Teacher:* Question 5 asks, "How much fluid do you think Joan Benoit lost?" And you were given the amounts to use for your calculations in the paragraph above. Anthony, what did you come up with?

*Anthony:* About 17 liters.

*Teacher:* Excuse me?

*Anthony:* About 17 liters.

*Teacher:* About 17 liters she lost? Wow, that's a lot.

[Many students grumble, indicating disagreement.]

*Teacher:* Hang on. Hang on. Mike, what do you have?

*Mike:* About 2.8.

*Teacher:* About 2.8, 2.9. We're talking liters. All right. Kirk, what do you have?

*Kirk:* Ah, 5.2 liters.
17:52 *Teacher:* 5.2 liters. Wow, we are all over the map here. Julio, what do you have?
*Julio:* 2.9 something.
*Teacher:* 2.9 something?
*Julio:* Yeah.
*Teacher:* Brenda?
*Brenda:* 2.8 liters.
*Teacher:* Okay. John Eaton?
*John:* I did, I think I might have done the calculations wrong. Actually, I definitely did. I got 72.5 liters. [Muffled laughter from students]
18:10 *Teacher:* That's a lot of liters!
(Koster, video transcript, March 18, 1999)

With regard to assessing student understanding, temperature taking allowed Ms. Koster to assess the extent to which a sample of students successfully solved the problem. When students' answers diverged significantly from her expected response, Ms. Koster shifted to a combination of funneling and probing assessment techniques to reveal students' interpretation of the problem.

[After coming to a consensus that Joan Benoit finished the race in approximately 140 minutes, Ms. Koster asks students to share how they found the liters of sweat lost during the race. Ms. Koster leads the discussion from the back of the classroom.]
22:25 *Teacher:* You know how much she loses every 10 minutes. How much?
*Student:* One-fifth. One-fifth.
*Teacher:* A fifth of a liter. About how many minutes are we going to calculate for her? Key word here, "about." [No response from students. Ms. Koster shifts to a funneling responses approach.] Kids. Look right here. How many minutes is she running?
*Students:* [Choral, mixed] 135. 140. 145.
*Teacher:* Somewhere between 135 and 145. Are we happy with, let's say, 140? Let's say you forgot to subtract that first 10 minutes when she really wasn't losing anything yet. So let's say we've got to figure out how much she lost for about 140 minutes. And we know how much she

loses every 10 minutes. How do you set that up? What does it look like?

*John:* Um—

*Teacher:* [To John] Go set up.

*John:* [Walks up to chalkboard.] I agree with the 140. Or I did 145 into groups of 10. So then I had 14.5 groups of 10—then I got those into groups of 5 'cause that would equal 1 liter since it's one-fifth for every 10 minutes. And then, 5 goes into—um—I just rounded [14.5 groups] to 15, and 5 goes into 15 three times. And so, I knew that I was going to be a little less than 3, so I said, like, it would be a little less than 3 liters.

*Teacher:* And look. What's the acceptable range?

[A student volunteers to explain his strategy and then forgets what he was going to say. Ms. Koster proceeds to write a ratio table on the board. Alex volunteers to share his solution method.]

*Teacher:* Speak really loudly, Alex.

25:30 *Alex:* One-fifth of water for every 10 minutes. So to get 1 liter, it would be 50 minutes. So, I multiplied 145 and then divided by 50. And that came up with 2.9.

*Teacher:* That's kind of cool. What you did is you figured out how to make this a whole number. So he said, "For every 1 full liter, that is—" How many minutes?

*Students:* Fifty.

*Teacher:* Fifty. Because if it's 5 times this, it would also be 5 times the number of minutes. That's a different way to think about it. What you have to see is if this figures for 10 minutes, how are you going to determine the unknown for about 140 minutes?

(Koster, video transcript, March 18, 1999)

In addition to monitoring student engagement, Ms. Koster used temperature taking to reveal a need for further clarification, explanation, or instruction. When Ms. Koster shifted from temperature taking to other discourse-based assessment methods, there was a noticeable difference in the cadence of teacher–student interaction. Students required more time to articulate their solution strategy, and more-complex approaches often needed to be clarified. To maintain the pace of the lesson, Ms. Koster guided the discussion to emphasize particular aspects of the problem. In the excerpt above, students wanted to deliberate the length of time for perspiration. After two students shared their method for finding the minutes of perspiration, Ms. Koster positioned the discussion to focus on the next part of the problem and bypassed further deliberation of what she perceived to be a moot point.

In addition to students' choral responses and group gestures, Ms. Koster also used student enthusiasm and responsiveness to questions as evidence to gauge whether students were ready to continue with the lesson. When student engagement and responsiveness were high, Ms. Koster increased the pace of the lesson and briefly addressed answers to tasks, sometimes questioning students immediately after the question was first read from the text. In contrast, when students were overtly disengaged or did not produce written work for an assigned problem context, she asked additional questions or modeled problem-solving processes to lead students to a point where they could more successfully engage in the problem context.

### Students Responding to Other Students

To promote student self-assessment, teachers need to give students opportunities to engage in processes of assessment, such as interpreting responses and providing feedback. One way in which Ms. Koster encouraged student self-assessment was through peer assessment. The following selection is an example of how Ms. Koster deferred the interpretation of one student's unexpected response to other students for further interpretation and feedback. This exchange demonstrates how Ms. Koster and her students contributed to instructionally embedded assessment by listening to one another and articulating their interpretations of one another's thought processes. In this excerpt, students are midway through the review of a homework assignment related to a problem from the Ups and Downs unit (Abels, de Jong, et al., 1998), in which the problem context asks students to find the growth factor of an aquatic weed. Previous problems in this section involved whole-number growth factors. This was the students' first investigation of a situation that involved a decimal growth factor. Table 10.1 was written on the board during this class discussion.

> The aquatic weed *Salvinia auriculata* also spreads by an annual growth factor. The first time it was measured, in 1959, it had grown to cover 199 square kilometers. A year later, it covered about 300 square kilometers. In 1963, the weed covered 1,002 square kilometers of the lake. The factor is not two, but another number. Use your calculator to find this decimal growth factor. (pp. 41–42)

**Table 10.1.** Table on the chalkboard during a homework discussion in Ms. Koster's class.

| 1959 | 1960 | 1961 | 1962 | 1963 |
|---|---|---|---|---|
| 199 | 300 | | | 1,002 |

[Ms. Koster is at the board asking students to describe the method they used to find the growth factor. Alexia has already shared that she found a growth factor of 1.5 but could not explain why it worked. Ms. Koster now shifts her attention to Kirk.]

*Teacher:* Kirk, what did you do?

*Kirk:* Actually, I got a whole different answer.

*Teacher:* Okay.

*Kirk:* I thought [the growth factor] was 0.5—because you're only adding half of that number to get 300. So I don't see why you need 1.5, 'cause if you times it by that much it would be, like, 500.

*Teacher:* Stop a minute. Where did you get the half a number, the 300 bit?

*Kirk:* [From his seat in the back of the classroom, Kirk points to a table on the board.] 0.5. [Kirk has puzzled look on his face.] Er, wait. Half—no, I took 199, half of that, which is the yearly growth, which is about 99.5. Which would equal 298, and that's about 300.

*Teacher:* [Writing the numbers on board, with arrows labeled with 0.5 leading from number to successive numbers] Is this what you're saying?

*Kirk:* Yeah.

*Teacher:* [To the class] So he's thinking the growth factor is 0.5. [Addressing Kirk] Am I understanding you correctly?

*Kirk:* Yep.

(Koster, video transcript, April 9, 1999)

As more students gave Kirk their attention, he became flustered and restated an incorrect account of his method. Instead of sharing her own interpretation of Kirk's method, Ms. Koster allowed Kirk to articulate it for himself. Even though Kirk gave a procedural explanation, established norms for student articulation (which emphasize student communication of thought processes) allowed other students to interpret and respond to Kirk's proposed strategy.

*Teacher:* Jacob, did you get 1.5 as your growth factor?
*Jacob:* Um hmm.
*Teacher:* Do you have any clue as to why or why not this [pointing to Kirk's method on board] stands as correct—or not?
*Jacob:* Well, I think it's incorrect. 'Cause if you do it on your calculator it doesn't work.
*Teacher:* So, you punched in this. And multiplied it by this. And what did you get? [Jacob mumbles.] And while he's figuring, here's part of the strategy of a successful thinker. [Ms. Koster moves away from the board to front center of the classroom to address all students.] Can you try to understand what he's saying so you can point out what maybe he needs to rethink? Or are you sitting there saying, "Whatever. It's Kirk." [Smattering of laughter] Try to understand his way of thinking. [This comment to Kirk is meant in jest. As the self-nominated class clown, Kirk takes the comment in stride and smiles.] Linda, help us out here. Guys, don't forget what you're going to say.
(Koster, video transcript, April 9, 1999)

Ms. Koster has now made the purpose of this interaction explicit and presented it in terms of a challenge. Ms. Koster's effort to have students respond to Kirk's method reflected her goal of having students appreciate the perspective of others and demonstrated an approach that she regularly used to include students in providing feedback to others. By leveraging Kirk's misinterpretation of growth factor, she provided a timely learning opportunity to reinforce the process of finding an exponential growth factor and how it should be represented. In the exchange that followed, the combined perspectives of Linda and Rudy provided other connections to the decimal growth factor that might not have occurred if Ms. Koster had corrected Kirk's method herself.

*Linda:* I don't think he's saying that you multiply it by 0.5; you add 0.5. Because when you multiply something by 1.5, all you're doing is—you're adding half the number that you multiply.
*Teacher:* Where did the 1 go?
*Linda:* The 1? If you multiply something by 1, it's the same number.
*Teacher:* [Turning to Kirk] Did you try this?

*Kirk:* Yeah, well I thought it was—um, I—adding 99—er—0.5 to it. Sort of. So— [Kirk does not appear to be persuaded by Linda. At this point in the lesson, the discussion moves on to another errant method for finding the growth factor. After 80 seconds, the discussion is redirected back to Kirk's method.]

*Teacher:* Interesting thinking, Kirk. Can you see why your way makes sense initially but probably doesn't work?

*Kirk:* Um, yeah. Um, no. Sort of.

*Teacher:* Okay. Then let's keep going. Rudy?

*Rudy:* If you just added 50% of the number you add, wouldn't it be the same way as thinking what Kirk was doing?

*Teacher:* Give me numbers to what you're saying.

*Rudy:* Alright. He was thinking about adding about half of 199. So, if you just added 50% of 199 onto 199, it would equal about 300.

*Teacher:* Okay. Take it the next step.

*Rudy:* And then if you keep doing it you'll eventually get to the answer. Just add 50% of 300 to 300, you'll get the next number.

*Teacher:* Whatever—it's just Rudy. Or do you understand what he's saying and can you put it into a different way of speaking? Hang on, Linda. Go, David.

*David:* If you times something by 0.5 doesn't it get smaller?

*Teacher:* I don't know. Do you have a calculator? [Many students are talking. Ms. Koster picks up on what Keith announces over the other students talking.] [To class] Pause in your mumbling. [To Keith] Say that again.

*Keith:* You have to add the 1 to the 0.5 so you keep the same number and then you add the 0.5. Otherwise, you make the number smaller.

*Teacher:* You've got the idea of what you're adding on. What you have to hang onto is what you already have. And how do you hang onto what you already have?

*Students:* [From many students] You add a 1.

(Koster, video transcript, April 9, 1999)

By devolving the interpretation of Kirk's response to other students, Ms. Koster used student–student interaction to provide feedback to Kirk's misconception of growth factor. A byproduct of this exchange was additional evidence of students' conceptions of growth factor. By deferring student misconceptions to other students, Ms. Koster was able to generate contrasting student responses, providing additional mathematical connections to the problem context that otherwise would not have been introduced.

## CONCLUSIONS

Ms. Koster's skill in generating rich classroom discourse allowed her to use it for classroom assessment. Her instruction depended on effective discourse-based assessment. From her years of teaching experience, Ms. Koster trusted her intuition to read whether students were "getting it" and to make appropriate on-the-fly adaptations to her instruction. Her knowledge of mathematics and of student learning allowed her to make informed decisions about the adaptations she should make. By design, her lesson structure was open and flexible, and she expected additional learning opportunities to emerge from student input. Because her teaching style was, by nature, practical inquiry (Richardson, 1994), she approached the implementation of a new mathematics curriculum as a chance to learn along with her students, with eyes and ears wide open.

This selection of vignettes demonstrates that instructionally embedded assessment is more than asking good questions. Student engagement is a necessary prerequisite to assessing student understanding. Without full engagement in a problem context, students' responses may underestimate their understanding of a mathematical concept or principle. As shown in the exchange between Kirk and his classmates, collaborative engagement in a problem context can create opportunities for peer assessment and sustained deliberation and sense making of a common misconception. Even within the scope of a teacher's questioning techniques, questions have different purposes in relation to assessment. Temperature taking allowed Ms. Koster to take a quick, albeit superficial, glance at "where students were." In contrast, students' responses to Ms. Koster's range of funneling and probing techniques elicited more substantive evidence of student understanding, while, at the same time, offering other students an alternative perspective on the same problem.

Importantly, Ms. Koster's perspective on assessment was formed prior to using MiC. Her willingness to experiment with new activities and curriculum was due, in part, to her comfort with dealing with the unexpected. As an experienced teacher, she had grown accustomed to developing lessons with a minimal amount of planning and preferred to construct instructional paths on the fly. I would argue that Ms. Koster, over time, acquired a dependency on discourse-based assessment to guide lessons, and her confidence in responding to students' needs as they emerged heightened her attention to student verbal communication during instruction. Even though this was her first time teaching the unit, when the interviewer asked how much of her planning was left to student reactions to the problems, Ms. Koster replied:

> Ninety percent. Having taught almost 20 years and not being floored by things going wrong, I trust myself to do that. I think to a new teacher or to a teacher who needs to be really overly planned, I would seem almost incompetent to them, knowing that I sort of trust that, "Okay, let's see what happens with this." I remain tuned in enough to know where to take it, or at least to take a best guess about where to take it. That's a large, large part.
>
> I don't think I am worth much if I have an agenda. . . . So, do I take a lot of prep time? Quite frankly, no. The time shift is at the back end when their stuff comes in and I take a look at it. The time in wandering around and looking over shoulders. And when I get really stumped with how we are doing. I know a couple of times I said, "Okay, look at the next one. Write down what you think. I am coming to look over your shoulders." Because—I don't know—I need a dipstick right now. (Koster, interview, March 26, 1999)

By observing students' work in progress, Ms. Koster was able to assess the pitfalls that students encountered. By interacting with students while they faced these challenges, she was able to assess whether students' struggles were related to the wording of the problem, contextual features of the problem, or limitations in their understanding of the mathematics required to complete the task.

To use discourse-based assessment, teachers must be sensitive to the social fabric of their classroom and be able to encourage interaction and participation, while at the same time respecting each student's confidence and comfort with sharing his or her knowledge, insight, and perspective. To effectively develop the learning environment required for classroom assessment, teachers must be sensitive to student affect and the need to promote and maintain productive relations among students.

When instruction is not supported by discourse-based assessment techniques, teachers overlook critical opportunities for student learning. Discourse-based assessment provides teachers a more substantial field for determining which features of mathematics problems challenge students. It allows teachers to evaluate which times students are prepared to engage in tasks and activities without instructional support. Student–student communication, adeptly facilitated in a principled manner, is more apt to shed light on prevailing student misconceptions, which then can be turned into timely learning opportunities. By leveraging student misconceptions in this way, teachers can use contrasting student responses to reinforce mathematical connections that otherwise would not be available through less flexible forms of classroom assessment.

In her final comment from the third interview, Ms. Koster recognized that her method of instruction, while seemingly natural for her, could pose challenges for teachers who require a high degree of predictability in their lesson structure.

> Let me phrase this delicately: If you don't think on your feet well, I think this is very threatening and difficult. We talked about this a bit yesterday: If you find yourself four and five times saying, "Well, that might work," then eventually, if I were a student in that class, I'd think, "This lady doesn't know what she's talking about." She can't say, "Great, you got it." "No, it doesn't work, can anybody tell us why?" And that's asking a lot [from teachers with different] teaching styles, to be very quick. Not even very quick. [To be] comfortable with "you don't have a lecture prepared" or "you don't have a presentation prepared." You kind of have to wing a lot of it based on what the kids bring back. For me, that's fun. Plus, I trust enough of my senses trying to figure out what the kid's saying or to guide the discussion so I can figure out what the kid's saying. (Koster, interview, May 6, 1999)

To realize higher aspirations for student understanding in inquiry mathematics, teachers will need to address not only their conceptions of assessment but also their conceptions of teaching and learning. The discourse-based assessment practices exemplified by Ms. Koster were consistent with her conceptions of teaching, her respect for student learning, and her instructional goals. To initiate the development of teachers' discourse-based assessment practices, teachers need opportunities to reflect on their conceptions of evidence for student learning of mathematics and to deliberate the validity of such evidence with other teachers. Teacher experimentation with curricula designed to elicit student explanation of strategies, along with the support of professional collaboration, also can be used to initiate the process of "professional problem solving." By observing other teachers through the lens of discourse-based assessment, teachers can improve and develop formative assessment techniques to accommodate increased student communication and different representations of student understanding. We hope that Ms. Koster's thoughtful articulation of her assessment practices will offer teachers a starting point for exploring discourse-based assessment, which fundamentally is based on ongoing communication between teacher and student to promote learning with understanding.