

SCAFFOLDING MATHEMATICAL DISCOURSE IN KINDERGARTEN: A PRACTICAL LOOK AT THE CHALLENGES OF SUPPORTING STUDENTS “IN-THE-MOMENT”

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Facilitating mathematical discussions where all students actively participate in making conjectures, providing clear explanations, and understanding each other's reasoning is a goal of mathematics instruction. This study documents one kindergarten teacher's attempts to help her students verbalize their mathematical thinking while solving problems in an addition and subtraction unit. The "pathways" that the teacher used to develop a community of learners in the classroom provide insight into understanding the complexities of facilitating successful mathematical discussions.

What does effective teaching of mathematics, and in particular primary mathematics, look like? We posit that effective teaching is evidenced by a lively math community where students think, talk, solve, invent, understand and produce. The effective teacher is a student of her students. She listens to and authentically engages with them as she guides mathematical conversation. However, we realize that effective practice is defined according to one's goals and assessment of what it means to do mathematics. Because our goal is for students to learn math with understanding, we set out to discover how a teacher teaches for understanding. What decisions, made “in-the-moment”, help to create a community where students engage in mathematical conversations that deepen their understanding of mathematics?

THEORETICAL FRAMEWORK

What Does it Mean to Understand?

Dewey proposed that to understand is to reflect and engage in purposeful inquiry (1916). Reflection and inquiry are fundamental mechanisms that transform *doing* into *trying* (principled, thoughtful action informed by careful observation) and *undergoing* into *instruction* (making specific, explicit connections between actions and consequences). He goes on to describe thinking as “the intentional endeavour to discover the specific connection between something which we do and the consequences which result, so that the two become continuous” (p.145). To understand, not only must we see *that* things are connected but *how* things are connected. Discovering the details of these connections is a natural by-product of what Dewey calls reflection.

Echoing Dewey as well as Piaget, Hiebert, Carpenter, Fennema, Fuson, Wearne and Murray (1997) say to understand something is to “see how it is related or connected

to other things we know” (p.4). Consider a child’s understanding of multi-digit operations. With absent strong base-10 understanding and experience composing and decomposing numbers, a child’s understanding of addition or subtraction with regrouping can degenerate to memorization of a procedure. As a child learning how to subtract numbers, one of the authors never could remember what to do when she needed to borrow from a zero. It seemed arbitrary that it should turn into a 9, why not a 7 or a 2? In this case, the knowledge that 10 ones was equivalent to 1 ten was disconnected from the standard algorithm for subtraction, and the process of regrouping. Children’s understanding of multi-digit operations differs based on the depth, details, and number of connections formed. Based on this working definition of understanding, we now consider how students develop mathematical understanding in a classroom setting.

Understanding and Mathematical Discourse

Beyond seeing connections and building relationships, understanding includes the ability to make those connections (i.e., one’s thinking) comprehensible to another (Lampert, 1998). This conception of understanding highlights the importance of communication, and is consistent with a dynamic view of mathematics where coming to know is a process of constructing and negotiating meaning within a community of peers. One consequence of this expanded definition of understanding is an increased emphasis on verbalizing thinking, explaining ideas and solution strategies, and active listening in elementary math classrooms. These instructional practices find broad support from the research community, as well as policy makers, and state and national curriculum standards (Carpenter, Fennema, Peterson, Chiang & Loef, 1989; Chapin, O’Connor & Anderson, 2003; Fennema, Carpenter, Franke, Levi, Jacobs & Empson, 1996; NCTM, 1989). Although teachers know that engaging students in mathematics discourse is a desired student outcome, they are often unsure of how to lead students to achieve these goals. As a research community, we have not provided sufficient practical support for teachers attempting to implement these practices.

Certainly research has documented teacher practices that facilitate students’ verbalization of their thinking such as revoicing, asking students to restate or build on other’s ideas, using wait time, etc. (Cazden, 2001; Chapin et al., 2003; Jacobs & Ambrose, in preparation). But, because participants in studies are often experienced teachers skilled at facilitating mathematical discussion, the complexity of scaffolding mathematical discourse and the time and patience it takes to acquire those skills can be obscured. Just because a teacher asks, “How did you solve that?” or, “Can you explain ...” does not mean students will automatically provide coherent explanations of their thinking, or that a teacher will then know how to connect their ideas to the appropriate mathematical concepts. The question still remains of how teachers make use of discursive tools in the real-time act of teaching as they deal with multiple, competing concerns to make split-second decisions.

In response to this, we chose to conduct research about the “how” of achieving these student outcomes with an inservice kindergarten teacher. We are presenting a realistic picture of the problems, issues, challenges and successes that arose for both the teacher and the students as they attempted to become skilled in clear mathematical communication. Scaffolding students in their ability to “talk mathematics” can be especially challenging in lower elementary grades where students are often unfamiliar with collaborative learning, are relatively inexperienced with listening to one another, and may have never had the experience of verbalizing and justifying their ideas. Studies show that it is possible to achieve these goals in kindergarten, but do not sufficiently explain how teachers support young children’s engagement in mathematical discourse over time (Carpenter, Ansell, Franke, Fennema & Weisbeck, 1993; Cooke & Buchholz, 2005).

METHODS

Because our research is based on issues and questions generated by the classroom teacher, we are engaging in collaborative action research. The teacher “drove” the research by selecting her own questions and areas of inquiry. In particular, her questions were: 1.) How can I scaffold students’ emergent and varying abilities to “talk mathematics” (“Talking mathematics” was the participating teacher’s terminology and was defined as participation in the discourse of mathematics by verbalizing, explaining and justifying one’s own and others’ ideas), 2.) How can I encourage students to become active listeners and engage critically with one another’s ideas? These, in turn, became our research questions. We added one additional question: How does the teacher support students who struggle to verbalize their thinking in whole-class discussions, and are there patterns and consistencies that might inform the development of a framework or model for eliciting student thinking?

Participants and Data Collection

The classroom teacher in our study (Ms. P) was in her 4th year of teaching (second year teaching kindergarten). There were 18 students in her ethnically diverse class (Hispanic: 4, African American: 3, Asian: 2, White: 9; Males: 11, Females: 7; ELL: 1). We were in Ms. P’s classroom at least once a week for her 30-45 minute math lesson during the 2006-2007 school year. During math lessons one of researchers took field notes while another videotaped the lessons. For this paper our focus is the Addition/Subtraction unit that took place from March to May. Primary data sources include transcripts of video footage and stimulated recall sessions with the teacher from the Addition/Subtraction unit, field notes, and the teacher’s journal.

Analysis

We used grounded theory (Strauss & Corbin, 1998) in our analysis, starting with open coding to identify main themes and patterns in how Ms. P scaffolded her students’ ability to “talk mathematics”. Initial analysis revealed regularities in

teacher-student interactions which we described as interactional pathways Ms. P and her students co-constructed. We refined our analytical categories and interactional pathways, looking for patterns and relationships in the data to support and refute our emerging findings. We also worked closely with Ms. P in the analysis phase, engaging in member checking to verify our findings and analysis.

FINDINGS

In order to identify how Ms. P scaffolded her students' entry into the discourse of mathematics, we looked for patterns in teacher-student interactions. We then specifically focused on the discursive moves she employed to facilitate students' verbalization of their mathematical thinking. The various combinations of scaffolding moves that routinely occurred in her classroom are represented as multiple *pathways* Ms. P and her students travelled down to communicate their mathematical thinking to each other (see Figure 1). In the following discussion we present examples of the different pathways Ms. P used to scaffold her students' ability to "talk mathematics", and identify factors that influenced her choice of pathways "in-the-moment".

In a typical lesson, Ms. P would pose a problem to the class (e.g., There are three boys playing in the housekeeping center. Two girls join them. How many children are playing in housekeeping?), provide time for individual or pair work, and facilitate a discussion. Our data revealed that simply inviting a student to share his or her solution strategy was often insufficient for eliciting a clear explanation (see pathways on the right side of Figure 1). In fact, the most interesting interactions in our data were those in which a student gave an unclear initial response. If Ms. P judged an initial explanation to be unclear¹, she had various pathways she could choose from to elicit student thinking. Consider the "housekeeping problem" stated above. When the teacher asked her students to explain how they solved this problem, Avi responded saying, "I was just thinking in my mind three and two." Ms. P judges this initial response as unclear and begins a "series of probes" to scaffold Avi's verbalization of his thinking (this pathway is highlighted with the bold questions that follow). Her goal is to elicit an explanation that is understandable to the math community.

T: Ok why did you pick those numbers?

Avi: Because uh you, the numbers (he holds up 3 and 2 fingers on different hands). Uh, when I was like four I found out that like, like when I was doing it. I was not even looking at my hands. I just did this (holds up three fingers), and I did that (holds up remaining two fingers) and I knew it was five.

T: Ok but why did you do that? Can you explain because maybe someone in here might not understand why you were doing that.

Avi: Because I didn't feel my, my f-f, anything touching this (points to his palm).

¹ We defined a *clear* explanation as one that was understandable to someone other than the explainer (i.e., another member of the math community and/or the teacher).

T: What do you mean?

Avi: I didn't feel like any fingers touching this part (points to palm). [We conjecture that Avi has associated the quantity five with no fingers touching his palm.]

T: Ok I'm not sure what you mean by that. What I'm asking Avi is **how did you know?** You got, that answer that you gave is exactly right but I was curious **how did you know to use the numbers?** You said three and two is five or three plus two equals five. **So how did you know you were supposed to be using three and two?**

Avi: Cuz I knew, I looked at my hands.

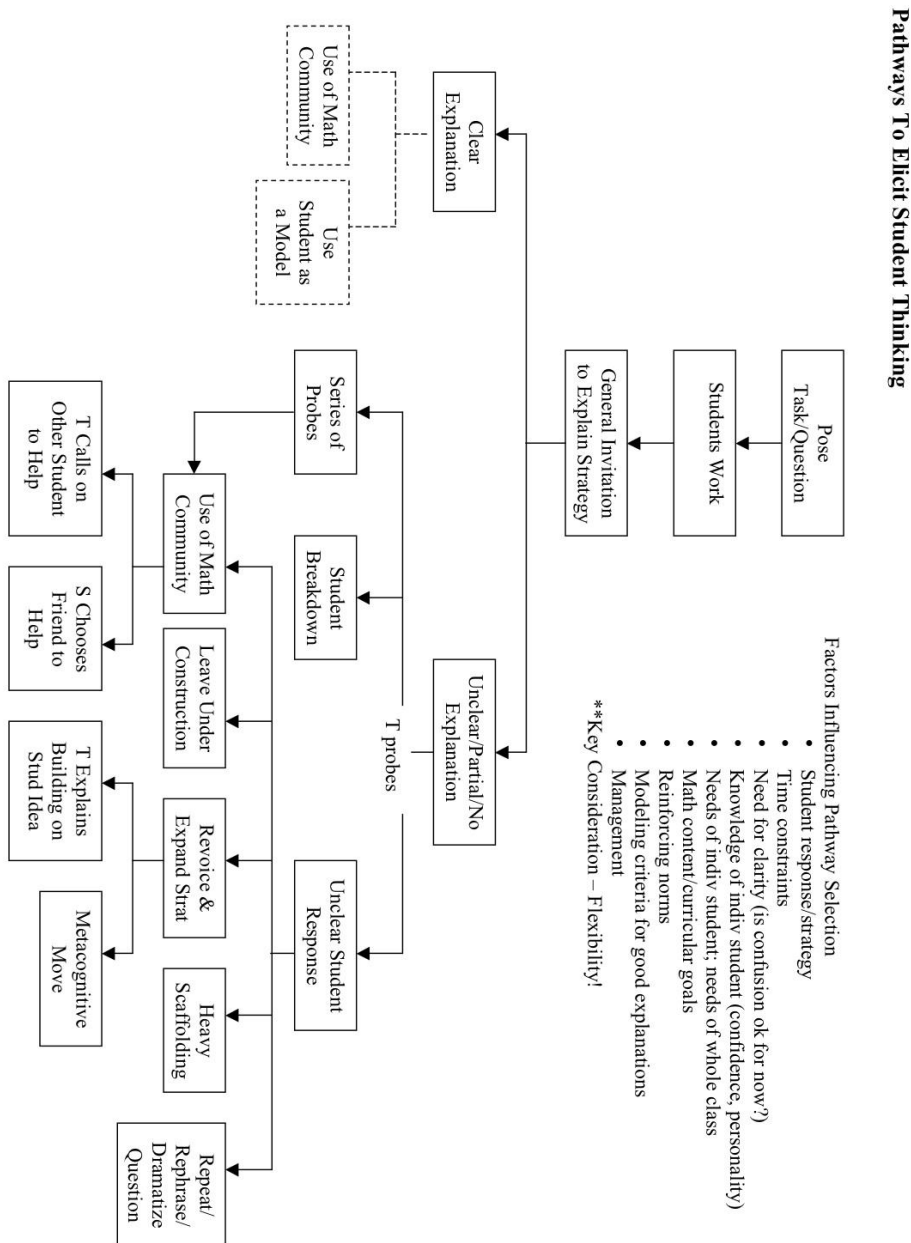


Figure 1: Pathways to elicit student thinking.

Language is often ambiguous, and, as this excerpt illustrates, speakers and listeners do not always understand one another in face-to-face communication. Avi and Ms. P are attempting to find shared meaning and to achieve a joint focus of attention (i.e., intersubjectivity) through a series of questions and responses. However, in this exchange Ms. P and Avi are not addressing the same question. Because their conversational referents do not match, a breakdown of communication occurs.

To understand why this happens, we need to consider the context, setting, and goals of this lesson and the larger curricular unit. This interaction (and the next) occurred during the first lesson in the addition/subtraction unit. The teacher's goals were not only clear student explanations and correct answers, but also for students to understand the process of problem solving. In fact, throughout the year Ms. P repeatedly emphasized that doing math in their learning community involved three things: listening, thinking, and sharing. One of her goals for her students, then, is metacognitive awareness of problem solving heuristics – where do the numbers one uses in solving problems come from, and when is it appropriate (and inappropriate) to choose your own numbers?

Although Ms. P engages in a “series of probes” and focuses on Avi's thinking, her questions constrain his response to a specific part of the problem solving process she deems important. She passes up a discussion of his thinking to make her point; only Avi does not oblige her. In reflecting on this, Ms. P mentioned the tension between her goals for the lesson and what kids do in-the-moment. One of her goals in this introductory lesson was to establish guidelines for solving addition and subtraction problems, one of which is the importance of listening to the story in order to know which numbers to use. Still, she went on to say, “If a student is not answering your question but says something great, you need to abandon your question.” In this interaction, Ms. P and Avi fail to produce a clear explanation, yet their “failure” illustrates the tensions and multiple, competing factors that influence teacher's real-time decisions. Responding to children and scaffolding their mathematical discourse involves decisions about how best to attend to the child while also attending to the teacher's goals and mathematical content.

Since Ms. P did not understand Avi's justification of no fingers touching his palm, she went on to “use the math community” (see pathway in Figure 1) and asked another student, Valerie, to explain her strategy.

Valerie: Um I was counting in my mind and I know that it was five.

T: Ok and so how did you get to five when you were counting?

Valerie: Um I was like counting in my head.

T: Can you say out loud what you were doing in your head?

Valerie: 1,2,3,4,5.

T: Ok and why did you stop at 5?

Valerie: Cuz I think it was five.

Here again the teacher went through a “series of probes” in an attempt to scaffold Valerie’s verbalization of her mathematical thinking. Ms. P’s questions serve two functions: to assess and to assist. Not only do the questions provide Ms. P with a better understanding of how Valerie thinks about addition, but her questions support Valerie’s thinking about the process of joining numbers, and raise metacognitive awareness – how did Valerie know when to stop counting? As with Avi, Ms. P’s probes are unsuccessful in eliciting a clear, cogent explanation from Valerie about her solution process. A notable difference, however, is that Ms. P does not press Valerie to answer the question of where three and five came from. Instead, she seems to have learned from her interaction with Avi and, for the moment, abandons her question and focuses on Valerie’s strategy.

Since one of the goals of teaching for understanding is eliciting clear communication of mathematical thinking (which did not occur in either of these instances), this raises questions of teaching effectiveness. Are these examples of effective teaching?² In the midst of partial and unclear student explanations we claim there is much to be positive about. As any witness to a Little Dribblers game can confirm, new basketball players sometimes pass the ball to the wrong team, dribble off their feet, and even shoot at their opponent’s goal. Despite these mistakes, spectators would not describe these youngsters efforts as failures or unsuccessful. They realize that learning how to play the game is a process where expertise and skill develop through experience. One learns to play basketball through the successes and mistakes made on the court. So, too, students learn how to talk math by doing it. And like a good coach, a teacher selects appropriate activities, has a clear goal in mind, models when appropriate, encourages and supports, and is a careful observer of her students’ actions and thinking. Although Ms. P’s goal is clear and complete explanations, her broader goal is supporting children’s beginning mathematical talk. She expects varying levels of clarity from her students, and through the various pathways provides each a way to legitimately participate in a community with a more knowledgeable other.

In addition to providing students with opportunities to talk mathematics, these “unsuccessful” interactions reinforced this math community’s classroom norms and expectations. These norms include: 1.) Telling an answer is not sufficient; the process is as important as the product, 2.) As a member of the math community, it is an expectation that each member provide clear explanations of his or her thinking that **others** can understand, 3.) It is important to rely on the community to challenge, clarify, and help you think, and 4.) It is okay to struggle and make mistakes.

DISCUSSION

Research ranging from the theoretical writings of Vygotsky and Bakhtin, the empirical studies of O’Connor (2001), Carpenter et al. (1989), and Fennema et al. (1996), and recommendations from national research panels in the United States

² The math community did eventually succeed in producing a clear explanation of the solution.

(NCTM's *Standards* (1989), and the National Research Council's *Adding It Up*) all encourage the use of discursive moves such as increased wait time, asking students to restate another's reasoning, and asking probing questions. Our study supports this earlier research and extends it by showing that very young students are capable of successfully verbalizing their mathematical thinking. As our excerpts illustrate, scaffolding mathematical discourse can be messy, as students can struggle to verbalize their ideas. Through the different scaffolding pathways, we present options beyond asking "how or why" for what a teacher might do to scaffold mathematical thinking and discourse for kindergarten students. However, these moves cannot be reduced to a formula. The very nature of authentic discourse demands flexibility and responsiveness. Our study is an attempt to capture the transient and complex nature of classroom discourse and how teachers respond "in-the-moment." Perhaps Ms. P put it best when describing her general approach to supporting student-generated explanations, "I would watch the student and listen to see how to progress from there. This is where flexibility comes in. My next move more often than not depended on the student's response."

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