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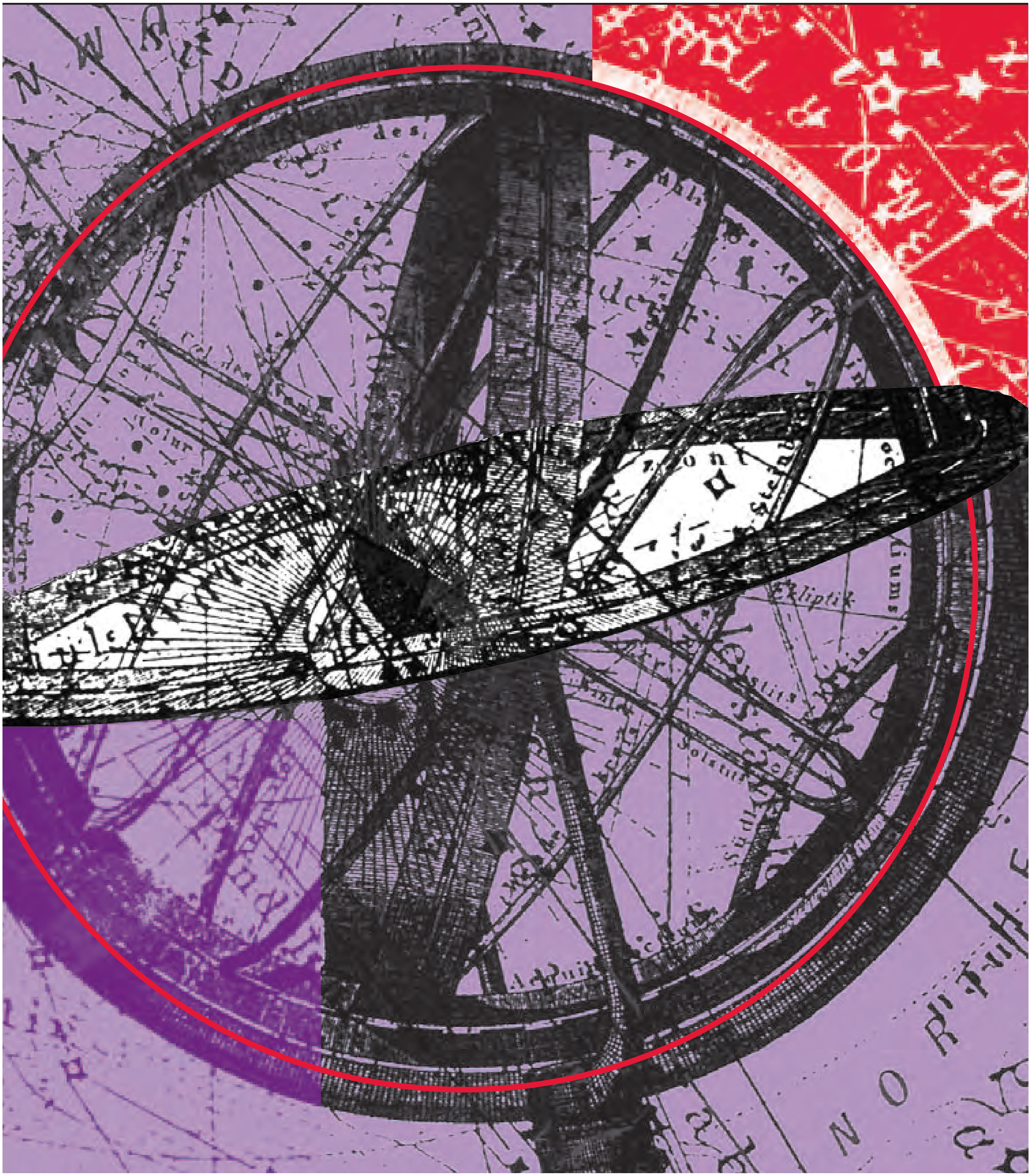

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A Framework for the Strategic Use of Classroom Artifacts in Mathematics Professional Development

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The use of classroom artifacts as a way to ground teacher professional development in the practice of teaching mathematics is generating considerable interest among teacher educators and researchers. Teacher educators have developed professional development around written student work, print and video cases, and videos of teachers' own classrooms. (Ball & Cohen, 1999; Driscoll et al., 2001; Kazemi & Franke, 2004; Schifter et al., 1999a, 1999b; Seago et al, 2004; Sherin, 2004) While many educators are enthusiastic about the use of these different artifacts of classroom practice in professional development, it is also important to recognize that artifacts, by themselves, do not guarantee teacher learning any more than having manipulatives in the classroom ensures that students will develop deep mathematical understanding (Ball, 1992; Ball & Cohen, 1999). Like manipulatives, classroom artifacts are only tools for learning; their effectiveness depends on how they are used.

The Turning to the Evidence (TTE) research project took on the challenge of articulating a framework to describe effective use of classroom artifacts in professional development and to connect that framework to teacher learning. By classroom artifacts, we mean materials that come from the classroom and that can serve as evidence of student and teacher thinking during the classroom lessons from which they are drawn. Video snippets and/or audio transcripts of students working, video of class discussion, or samples of written student work are all examples of classroom artifacts. TTE studied the use of classroom artifacts in two different professional development contexts, and the Strategic Use of Classroom Artifacts framework grew out of a need to articulate the nature of the use of classroom artifacts under study in these two contexts.

The first step is to define the purpose for their use. Classroom artifacts in a professional development setting can be used in many different ways, with many different purposes. For example, many teachers look at student work to assess students' learning or as a springboard for discussing issues of curriculum or instruction (Allen, 1998; Falk, 2000; Project Zero, 2001; Weinbaum et al., 2004). In the TTE study, classroom artifacts were used as data about students' mathematical understanding. In both of the professional development programs we studied, the purpose of the artifacts was to help teachers learn to use the data to inquire into the mathematical ideas that students were working on, students' understanding of these ideas, and the tasks of teaching that help promote deeper student understanding. An explicit goal of both programs was to help teachers internalize such an inquiring stance toward classroom artifacts and to begin to use them to better understand their students' mathematical thinking (Driscoll & Moyer, 2001; Driscoll, et al., 2001; Seago, et al., 2004).

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The Professional Development Programs

The two professional development programs used in the TTE study, Learning and Teaching Linear Functions (LTLF: Seago, Mumme, & Branca, 2004) and the Fostering Algebraic Thinking Toolkit (ATT; Driscoll et al., 2001), were both designed specifically around the use of classroom artifacts. Teachers participating in LTLF seminars work primarily with video cases of classroom mathematics discussions that were selected to highlight different aspects of student thinking about linear relationships. Teachers participating in ATT seminars work with a wider variety of classroom data (written student work, transcripts of students working in small groups to solve problems, records of teachers' questions to students in the classroom), which come primarily from their own classrooms. In the TTE study, seminars for each program were facilitated by the lead author of those professional development materials, thereby assuring that the seminars would be implemented with a high degree of fidelity (Seago, 2006).

These two programs share an underlying philosophy and a number of critical design features that are characteristic of the class of practice-based professional development programs: they offer coherent and extended opportunities for teacher learning (specifically, monthly, three-hour sessions for up to two years), focus on understanding and promoting student learning, connect to classroom practice, involve teacher collaboration, and seek to promote and support deep changes in both cognitive and behavioral aspects of teaching (Ball & Cohen, 1999; Hawley & Valli, 1999; Loucks-Horsley et al., 1998; Thompson & Zeuli, 1999). Both programs focus on algebraic thinking, aim to help teachers develop greater sensitivity to their students' mathematical ideas, and gain a deeper understanding of the algebra they teach. They seek to promote teacher learning by centering professional development activities around analysis, discussion, and reflection on classroom records and artifacts. Both programs also broadly organize professional development activities into two major activities: (1) opportunities for participants to explore and discuss the mathematics problems that they will encounter in the artifacts, and (2) inquiry into the artifacts themselves.

A major goal of both programs we studied is specifically to use classroom artifacts to help teachers develop the mathematical knowledge necessary for teaching (Ball & Bass, 2003; Ma, 1999) by promoting deep, sustained inquiry into both the mathematics underlying the problems used in artifacts and the student thinking embodied in them (and, where relevant, also the teacher thinking). To this end, activities are structured (and facilitated) to help teachers do the following: generate and recognize different solution strategies, make connections between different solutions and the underlying mathematics of the problem, compare and contrast different representations in terms of the mathematical ideas they highlight, and explore the mathematical thinking embodied in the artifacts. In addition, the programs seek to cultivate a disposition toward inquiry by encouraging a curiosity about the thinking captured in the artifacts and a tendency to generate and consider alternative interpretations.

Strategic Use of Classroom Artifacts

In order to study the teacher learning in these professional development contexts, we needed to articulate the facilitators' specific goals and strategies for using classroom artifacts. The result of this effort is the Strategic Use of Classroom Artifacts framework. We began the process of developing the framework by tapping the program developers' many years of experience in using artifacts in professional development. We then refined the framework through analysis of videotapes of the two professional development programs as they were implemented during the TTE study.

This paper describes and illustrates the Strategic Use of Classroom Artifacts (SUA) framework (see Table 1). In addition to its research application, we have found that the SUA framework can be used by people involved in the design and implementation of professional development centered on artifacts of classroom practice. The framework highlights the importance of helping teachers establish a disposition to attend to both the mathematical content captured in the artifact and the nature of the thinking (and understanding) that it captures.[1] These two ways of looking at classroom artifacts (i.e., with an attention to the thinking they capture and with an attention to the mathematical content) certainly overlap at times, and often are intentionally integrated. We have separated them for the purposes of explicating the framework because each serves

[1] Because the context of the TTE study was mathematical (algebraic) thinking, the framework is organized in terms of mathematical content. However, we believe that the general focus of the framework (on attention to content and attention to thinking) could be modified to address examination of classroom artifacts in other content areas.

TABLE 1: *Strategic Use of Classroom Artifacts Framework*

Attention to Thinking	Attention to Content
1. expressing curiosity about the thinking behind artifacts	1. considering the mathematical ideas underlying the work represented in the artifact
2. distinguishing between description of work represented in artifacts and interpretation of it	2. using a guiding framework to discuss the mathematics content in artifacts
3. grounding interpretations of thinking in evidence from artifacts	3. making connections between the mathematical ideas represented in the artifact and related mathematical ideas
4. generating plausible alternative interpretations of thinking, and supporting these with evidence	4. comparing/contrasting different representations of mathematical ideas represented in artifacts
5. seeing strengths (not just weaknesses) in the thinking and understanding captured in artifacts	5. using the exploration of the mathematics represented in the artifacts to develop/engage norms of mathematical argument
6. developing plausible story lines about the student or teacher thinking behind the work	6. comparing/contrasting mathematical arguments and solution methods represented in artifacts
7. making connections to previously studied artifacts to compare/contrast the thinking in the artifact currently under study	7. making connections to previously studied artifacts to compare/contrast the mathematical ideas under consideration
8. using discussion of the thinking represented in artifacts to connect with issues of one's own teaching practice	8. using discussion of content represented in artifacts to connect with issues of one's own teaching practice

Links to Practice: Teachers think about and discuss
1. their own and others' classroom dilemmas
2. the kinds of student reasoning and understanding they see (and don't see) among their own students
3. how to promote deeper understanding among students
4. the mathematical ideas elicited by different mathematical tasks and problems
5. how different mathematical tasks and problems will generate evidence of student thinking in the classroom

as a somewhat different lens on the use of classroom artifacts.

To briefly illustrate the kinds of attention to student thinking the framework is meant to highlight, consider the following excerpts from transcripts of conversations among teachers in one of the ATT seminars. These are taken from the final (13th) session of the seminar, during which time teachers studied three students' solutions to the Crossing the River problem. In the following excerpted conversation Linda, a high school teacher, and Tara, a fifth grade teacher, are working together, trying to follow the thinking of "Student A" (see Figure 1).

Linda and Tara are focusing on question 5c, which asks what happens to the rule if [any number] of adults and 11 children need to cross the river.

Linda: Oh wait a minute, they're saying repeat this nine times, so two kids across and one kid comes back, you repeat that nine times that's eighteen, one adult crosses, one kids comes back, two kids cross, one kid comes back, repeat that A -1 times, so let's say we have eleven kids, and let's just say five adults, which would be 5 x 4 would be 20 trips to cross, and the kids were 22 – 3, which would be…

Tara: 19

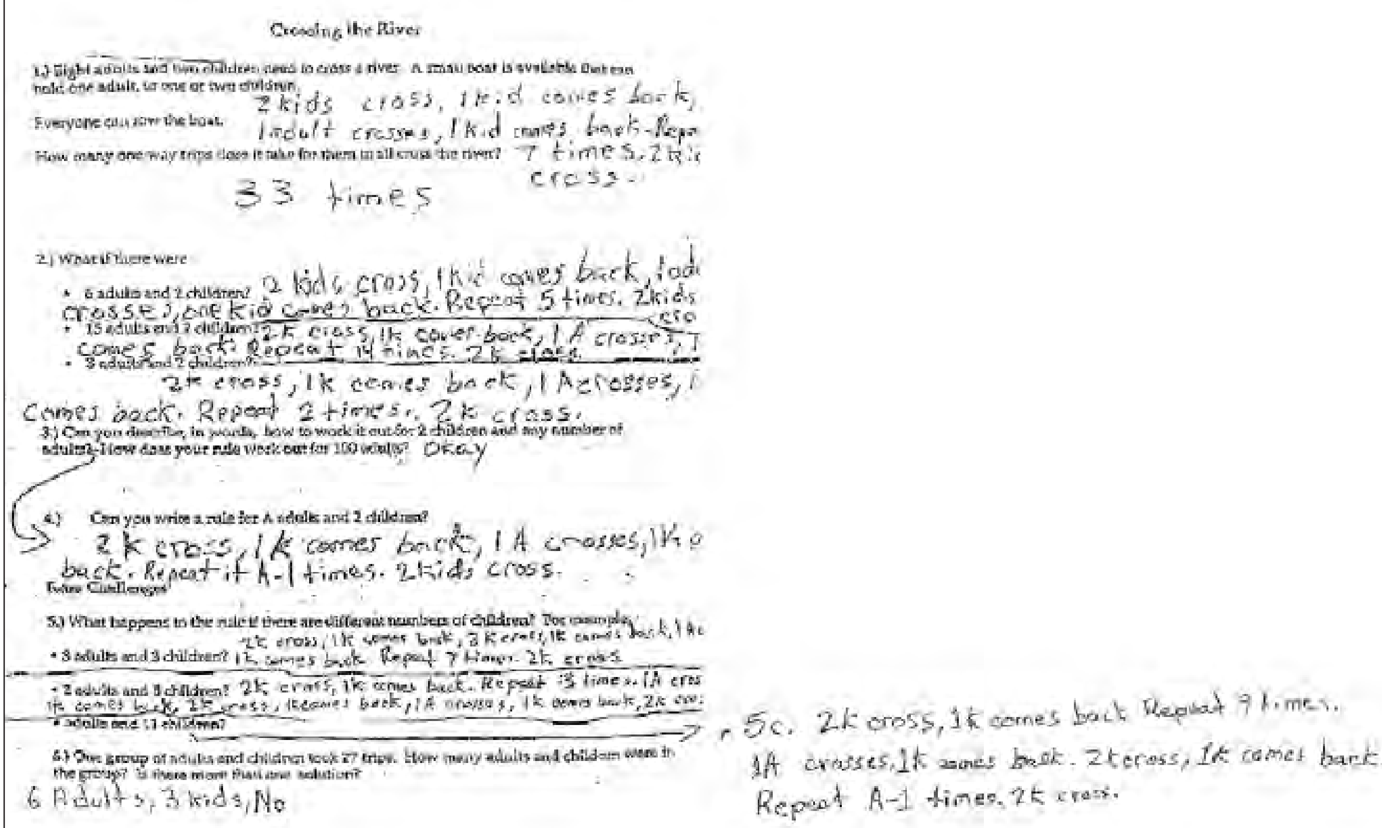
Linda: thank you, that would give us 39 trips, so this is 18, yeah, they're off one. But then…

Tara: Because they forgot that the kid needs to go back. Is that why they're off?

Linda: I don't know.

[2] All names of teachers are pseudonyms.

FIGURE 1: ***Student A's work on Crossing the River***


Crossing the River

1.) Eight adults and two children need to cross a river. A small boat is available that can hold one adult, or one or two children.

Everyone can row the boat.

How many one-way trips does it take for them to all cross the river?

2 kids cross, 1 kid comes back, 1 adult crosses, 1 kid comes back-Repeat 7 times, 2 kids cross.

33 times

2.) What if there were

- 6 adults and 2 children? 2 kids cross, 1 kid comes back, 1 adult crosses, one kid comes back. Repeat 5 times. 2 kids cross.
- 15 adults and 2 children? 2k cross, 1k comes back, 1 A crosses, 1 k comes back. Repeat 14 times. 2k cross.
- 3 adults and 2 children? 2k cross, 1k comes back, 1 A crosses, 1k comes back. Repeat 2 times. 2k cross.

3.) Can you describe, in words, how to work it out for 2 children and any number of adults? How does your rule work out for 100 adults? Okay

4.) Can you write a rule for A adults and 2 children? 2k cross, 1k comes back, 1 A crosses, 1k comes back. Repeat it A-1 times. 2 kids cross.

Extra Challenges

5.) What happens to the rule if there are different numbers of children? For example:

- 3 adults and 3 children? 2k cross, 1k comes back, 2k cross, 1k comes back, 1A ... 1k comes back. Repeat 7 times. 2k cross.
- 2 adults and 5 children? 2k cross, 1k comes back. Repeat 3 times. 1A cross, 1k comes back, 2k cross, 1k comes back, 1A crosses, 1k comes back, 2k cross.
- adults and 11 children? → 5c. 2k cross, 1k comes back. Repeat 9 times. 1A crosses, 1k comes back. 2k cross, 1k comes back. Repeat A-1 times. 2k cross.

6.) One group of adults and children took 27 trips. How many adults and children were in the group? Is there more than one solution?

6 Adults, 3 kids, No

Tara: Two kids across one kid comes back [mumbles] see the kid needs to get back again.

Linda: This is off too though — "repeat A-1 times" to get the adults across. [mumbles] which would be four times, and then two kids cross which would be one time. Now they seem to realize in the end that two kids have to come back across. I think that's what that is. So that's 23.

Tara: I'm trying to think what their strategy would be. They did chunk that by trips. You know what I mean? By words, they chunked by words.

Here, the teachers begin to move slips of paper representing children and adults back and forth to help follow the student's solution

Tara: Now they're starting to get the adults.

Linda: Right, but they're trying to get the kids across….Now to get an adult across. One adult crosses, one kid comes back. Two kids cross. This person comes back. One kid comes back. Why are two kids crossing now, why are they not sending an adult? Two kids cross, one kid comes back, then repeat that. One adult, there's one trip, two trips, three trips, four trips.

Tara: Are they the same? Subtract here? Repeat…

Linda: Would that work? Three adults we would make one, two, three, four. One, two, three, four trips. For each. No, that doesn't seem right. . . .

In this excerpt, Linda and Tara both express curiosity about the thinking behind the piece of student work they are examining (Attention to Thinking #1), asking questions about what the student could mean by the instructions for moving A adults and 11 children. As they do so, they try to re-enact the students' solution methods, grounding their interpretations of Student A's thinking in the written evidence (Attention to Thinking #3). The teachers alternate between stating parts of the rule that the student wrote on his or her paper, and offering interpretations of how that rule might make sense to the student and/or as a problem solution. Furthermore, Tara attends to the mathematical content (Attention to Content #2) when she hypothesizes about the student's use of chunking. (Chunking is an element in the algebraic habits of mind framework that guides the ATT seminars.)

When the teachers convene as a whole group, they work together to reconcile their various interpretations of the student's thinking.

> Linda: We were just trying to figure out. . .where that was coming from, the nine times, the A-1, the two kids across, just what exactly was the logic going on here. . . . We kind of figured out where the '9 times' comes from but I don't think we figured out where the A-1 came from, and then the two kids cross was the two kids coming back at the very end. But to get the 5c — to get the eleven kids across they needed to do a repeat of that first 'two kids across — one kid comes back' nine times.
>
> Tara: At first we thought they forgot that last trip but then we saw at the very end of the problem they remembered those two kids need to come back.
>
> Mikki: Wasn't their A-1 the number of adults minus one? Because they acted out getting the first adult over, so there's your four trips, and then repeat it A-1 times.
>
> Darcy: If there is, because if there's only one adult — so 'one minus one.' you repeat it zero times and then two kids cross.
>
> Linda: Oh! Yeah maybe because it got cut off on that one. Maybe they were thinking there weren't any adults. Is that what you're saying?
>
> Darcy: Yeah, because it just says, it doesn't say adults, wait, what was the original problem…adults A and eleven children, so maybe they knew it was a variable and any value can go in and if it is that's what you need to do…
>
> Linda: But it should be adult, repeat A times — not A-1…
>
> Darcy: But no, they already got one adult over.
>
> Linda: Where?
>
> Darcy: After it says repeat 9 times, then it says, 'one A crosses, one kid comes back, two kids cross, one kid comes back, repeat A-1 times,' and then two kids cross.
>
> Linda: So then you're defining repeat as not including the first round. So when they repeat that other thing nine times they've actually got two kids, they have an extra step in there.
>
> Facilitator: So if repeat means include the first step they've got too much?
>
> Linda: Exactly.
>
> Facilitator: And if repeat means just don't cross the first one then…
>
> Linda: Then they're short.
>
> Tara: They mean don't count the first one, I think, because in [problem] number 4 they do the same thing, 'repeat it A-1 times.'
>
> Cammy: I took it to mean this is the pattern, repeat it A-1 times. […]

Here, we can see teachers calling on the evidence from the written student work to support their different conjectures about what Student A means by "repeat 9 times" (Attention to Thinking #3 and #4). Tara's last comment (". . . in [problem] number 4 they do the same thing, 'repeat it A-1 times' ") seems to be an effort to develop a plausible story line for this student's thinking by looking for consistency in how the student approached different problems (Attention to Thinking #6). She reasons that, if Student A's meaning of "repeat" was reasonably clear in problem 4 (i.e., "don't count the first set of instructions as part of the repeat), then the instructions probably mean the same thing in problem 5.

The final portion of transcript, also from the whole group discussion, illustrates ways the teachers attend to the mathematical content of the artifact. Here, teachers use the algebraic habits of mind framework to shape their discussion (Attention to Content #2) and consider the representations of mathematical ideas used by the students (Attention to Content #4).

> Facilitator: Often, going into student work provides me a new way of looking at the mathematics, some insights into the mathematics itself, was any of that going on, I think you said it was happening for you, Mikki?

> Mikki: We had solved the problem, and we came up with for when they changed the number of children 4A for the adults plus 2 x the number of children minus three, and the numbers worked out and I accepted that as the answer but I didn't know where the minus 3 came from until I looked at student B who was looking at it separately as the going and returning … the way that the child broke it up into 2a for one way and 2a for the other…the way his or her formula was very explanatory of the actual process, and he was the one who actually drew the model that went along with his thinking.

> Wally: . . .Student A, he chunked the cycle times the number of times it was repeated then brought the kids back. Whereas. . .Student B was very much into, he built this model, and he compared the number of trips to go over across the river and the number of trips to come back, so there was one more trip to cross the river then there were coming back in all of them, and the third fellow did a very different approach…Student C comes in and it's like, six adults times 2, times 2. Now, I don't know if that was a different approach to chunking because 2 x 2 is the 4. A different way to basically put the chunking down or…

These transcript excerpts illustrate two categories of the SUAs: how teachers' discussions of classroom artifacts focus on student thinking and on the mathematical ideas represented within them. In addition, the framework includes a "Link to Practice" category, which makes explicit the connection to classroom practice.

Using the Framework as a Tool for Professional Development

While we originally developed this framework as a research tool, it soon became apparent to us that it could also serve as a professional development tool, offering a coherent articulation of goals to guide professional development experiences that are grounded in the use of classroom artifacts. By identifying areas of attention that teachers don't necessarily gravitate to on their own, the framework can help provide guidance for developers, facilitators, and participants regarding effective use of classroom artifacts. Facilitators can model, highlight, and elicit the kinds of behavior and thinking included in the framework. For example, in the final transcript excerpt above, it is the facilitator's question about mathematical insights that initiates the conversation about representing the solution in different ways.

The idea of the framework is to provide a lens for focusing the work of the facilitator, as well as for interpreting the participants' thinking: both play an active role in shaping the discussion of the classroom artifacts. Facilitators may choose to explicitly share the framework with teachers so they can examine their own lenses on analysis of classroom artifacts, and also have a guide for the kind of discussion in which they should be engaging. Furthermore, facilitators and researchers can use the framework as a guide for examining teachers' learning over the course of practice-based professional development.

Having explicit guidelines and strategies can be useful both for creating new professional development materials and for helping facilitators to effectively use classroom artifacts in professional development settings. In terms of creating new materials, we hope that our articulation of guidelines and strategies will encourage discussion among developers regarding goals for teachers' use of artifacts as data for inquiry and the challenges involved in producing professional development programs that do so. Though there are currently a number of very thoughtfully constructed programs available (e.g., Barnett, 1998; Lampert & Ball, 1998; Driscoll & Moyer, 2001; Driscoll et al., 2001; Merseth, 2003a, 2003b; Miller & Kantrov, 1998; Seago, Mumme, & Branca, 2004; Schifter et al., 1999a, 1999b), for the most part their developers have not been explicit about the principles that guided their creation.

Additionally, a potentially promising use for these strategies is an articulation of the kinds of artifacts are useful for different kinds of inquiry. Just as not all manipulatives are useful or good for teaching every mathematical idea, it is likely that different kinds of artifacts are useful for helping teachers examine (and develop) different aspects of their practice. This kind of analysis would lead to more judicious and targeted use of artifacts in professional development. By providing a starting point for this line of thinking about the use of different types of classroom artifacts, and by articulating the specific ways that classroom artifacts can be used in professional development, the SUA framework can be used as a jumping off point for examining more closely the goals and learning outcomes of using classroom artifacts in professional development.

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