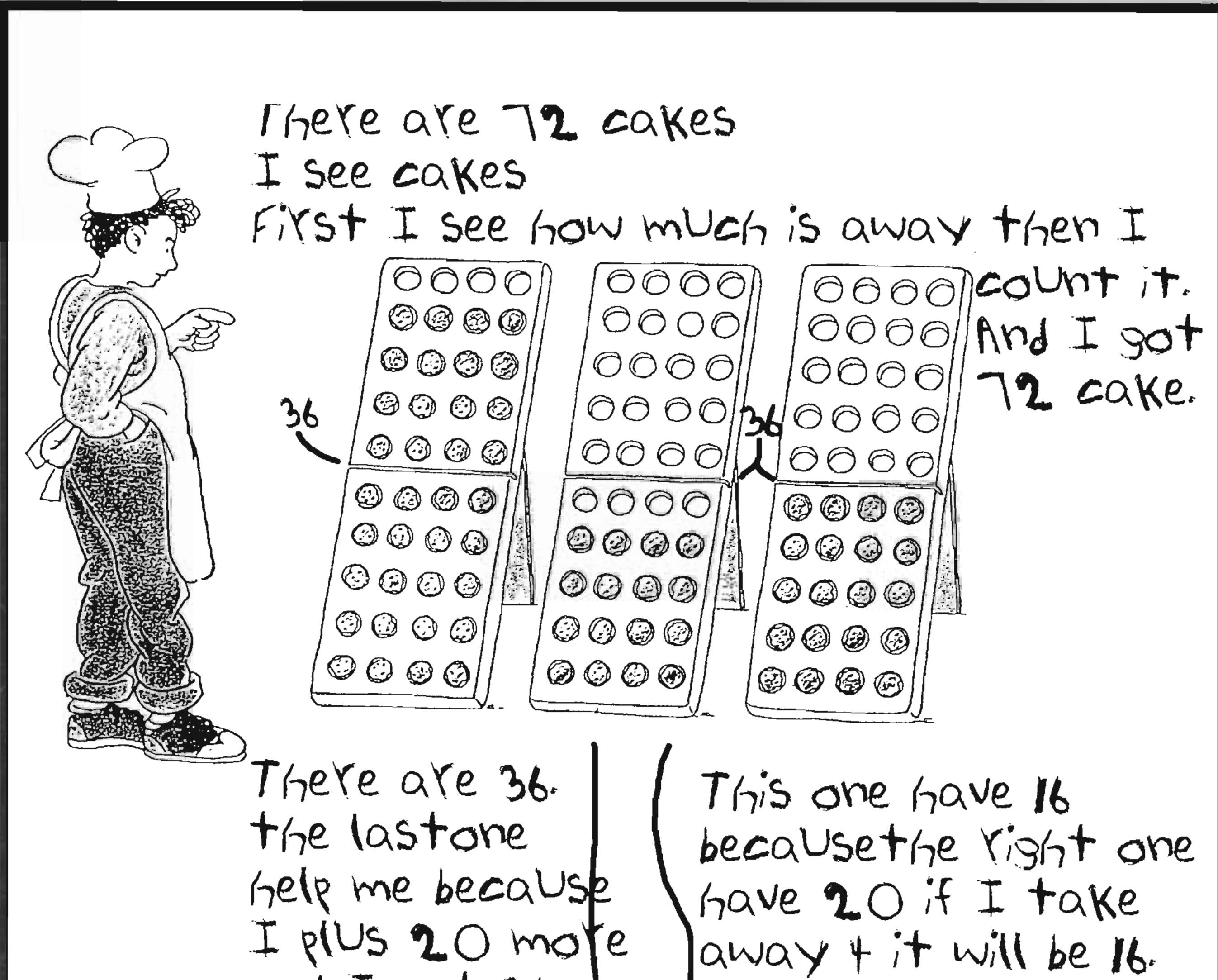
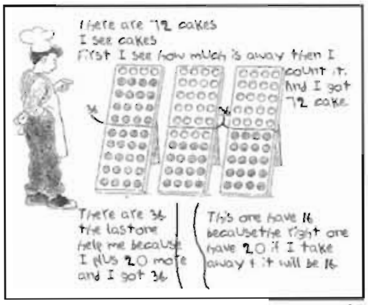
THE CONSTRUCTIVIST

Magazine of the Association for Constructivist Teaching

Volume 13, Number 2 Summer 1998

ASSOCIATION for CONSTRUCTIVIST TEACHING





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A Letter from the President of the Association for Constructivist Teaching

Dear Members,

I know you will find this issue of *The Constructivist* both stimulating and challenging. Catherine Twomey Fosnot has edited another outstanding set of articles for our membership.

A few months ago, on October 22 and 23, 1999, we "met in St. Louis" at a world-class fair that included presentations, workshops, and networking opportunities. About 350 people from all across the country attended to share ideas and research on various issues.

Our keynote speaker on the 22nd was Karen Gallas, a noted teacher researcher who has authored several books documenting her studies. They include three books published by Teachers College Press: *The Languages of Learning: How Children Talk, Write, Dance, Draw, and Sing Their Understanding of the World; Talking Their Way into Science: Hearing Children's Questions and Theories, Responding with Curricula;* and *Sometimes I Can Be Anything: Power, Gender, and Identity in a Primary Classroom.*

John Bransford, who was the keynote speaker on the 23rd, is Centennial Professor of Psychology and Education and codirector of the Learning Technology Center at Vanderbilt University in Nashville, Tennessee. He has authored several books and articles and is an internationally renowned scholar in cognition and technology. He and his colleagues at Vanderbilt have developed and tested innovative computer, videodisc, CD-ROM, and internet programs, including *The Adventures of Jasper Woodbury*, a problem-solving series in mathematics, the *Scientists in Action* series, and *The Little Planet* literacy series. They are also working with school systems on a Challenge Grant designed to improve instruction through innovative uses of technology. Bransford recently cochaired the National Academy of Science Committees that wrote *How People Learn: Brain, Mind, Experience, and School;* and *How People Learn: Bridging Research and Practice.* He was recently awarded the Sullivan Prize at Vanderbilt for outstanding research and has been elected to the National Academy of Education.

Breakout sessions at the conference addressed a broad array of subjects, ages, and research, with presenters from many states. Besides addressing core content areas, session topics were as wide-ranging as "Music across the Curriculum," "Constructivism and Children with Learning/Behavior Disorders," "The Value of Cooperative and Competitive Games in Early Education," and "The Littleton Tragedy: A Constructivist Perspective."

This year, the conference will be held in Atlanta, Georgia, with tentative dates of October 19–20. Faculty from Georgia State University will cochair the conference, and we can look forward to another round of stimulating discourse on constructivist issues, principles, and practices…as well as a taste of legendary southern hospitality. See you all there.

—Brenda Fyfe

A Letter from the Executive Editor of *The Constructivist*

Dear Readers,

It gives me great pleasure to present this focus issue on mathematics education. Much of the reform in mathematics education resulting from the NCTM standards has been described as "constructivist-based practice." Unfortunately, this practice has often been misunderstood to be a host of pedagogical strategies such as cooperative learning, the use of manipulatives, and the posing of word problems to children in order to elicit their invented strategies. While these strategies may sometimes be beneficial, they are in no way sufficient to ensure mathematical development, nor do they necessarily connect to constructivism.

The first article in this issue, by Betina Zolkower, addresses the role of context in learning and helps us understand better the difference between boring school-type word problems and truly problematic situations. Zolkower argues, along with the mathematician Hans Freudenthal, that real mathematics requires "mathematizing" one's world—seeing, asking, and investigating mathematical questions as a way of making meaning.

The second article, by Judit Kerekes and me, stems from the same perspective on the role of context but explores specifically the topic of beginning multiplication. We show how children's strategies change when the context has built-in constraints, and we use this research to delineate the important role of the teacher in designing contexts to ensure development.

Contexts are important for investigation and inquiry, but mental math mini-lessons are also critical in order to hone computation strategies. Shevell and DiBrienza's article—the third in this issue—describes the use of "strings" in mini-lessons to develop a repertoire of computation strategies and to ensure the development of number sense.

Hopefully, readers will find these three articles helpful in distinguishing between a practice that is truly based on a cognitive, constructivisit view of learning and one that is characterized by superficial pedagogical strategies.

Lastly, an issue would not be complete without a call for manuscripts. If *The Constructivist* is to reach its true potential as a reform tool, we need many good articles from professionals who are engaged in the difficult work of translating theory into practice. Articles should be approximately ten pages in length and written in a colloquial style, with references cited according to APA guidelines. We especially seek articles that speak to practice, and we encourage you to submit illustrations (graphics, photographs, etc.,with appropriate written permissions) along with your text. Please send manuscripts to Catherine Twomey Fosnot, City College of New York, NAC 3/217, 138th St. and Convent Ave., New York, New York 10031.

—Catherine Twomey Fosnot

Letters to the Editors

The editors of *The Constructivist* want your feedback! Please send all Letters to the Editors to Catherine Twomey Fosnot, City College of New York, NAC 3/217, 138th Street and Convent Avenue, New York, New York 10031.

Turn to page 26 for other highlights from the 1999 ACT Conference in St. Louis…

Bridging the Gap between School Mathematics and Common Sense: A Realistic Turn

Betina Zolkower

Traditional math instruction, Zolkower argues, excludes real life and suspends common sense. In this article, she makes a case for realistic contexts, presenting both their values and possible sources.

Mathematics in the City is an inservice project that involves almost 200 elementary school teachers working in five different school districts in New York City, which has one of the largest and most diverse school systems in the nation. Many of these teachers work with a great number of students from low socio-economic backgrounds as well as students who speak English as a second language. For over four years, while working in the midst of overwhelming pressures and constraints, Mathematics in the City staff have helped teachers reinvent mathematics and its didactics while bridging the gap between school mathematics and common sense.

Due to its collaboration with the Freudenthal Institute at Utrecht University in the Netherlands, the project has benefited from the influence of realistic mathematics education (RME), a theory that has been developing since the late 1960s around the work of Hans Freudenthal. Freudenthal (1973) defined mathematics as a human activity: mathematizing reality, reflecting upon this activity, and mathematizing mathematics. Mathematizing reality means organizing it with the use of tools such as objects, operations, and models that, over the centuries and with the contribution of different cultures, have come to constitute mathematics as a field of knowledge.

Following are some situations we use in Mathematics in the City as a starting point for mathematizing.

"The windows look so worn out! Maybe they will want to put new ones, so they first need to know how many there are," commented David, a third grader, in face of this fragment of modern urban life (see Figure 1). As they figure this out, children's

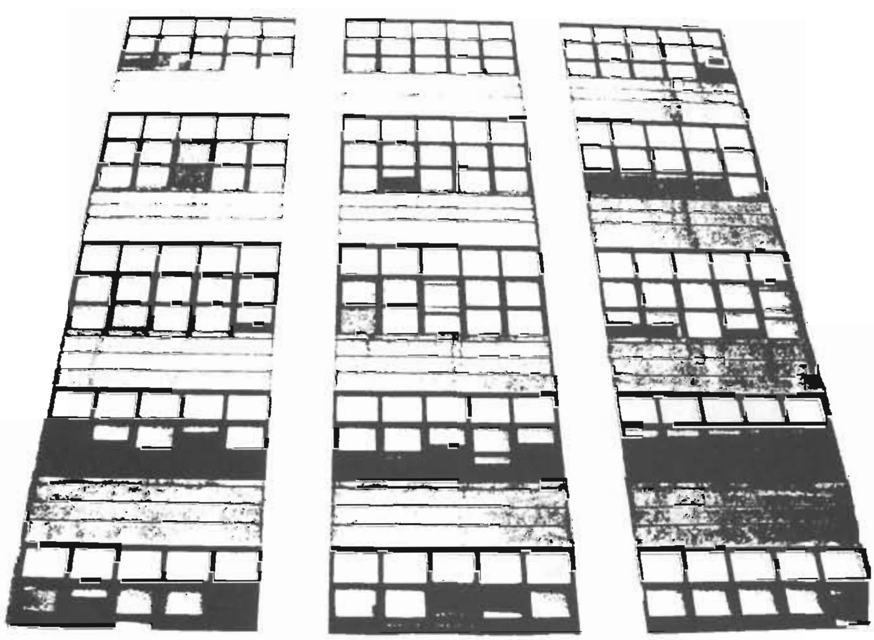

Figure 1. Windows: A photograph

strategies span all the way from counting the windows (one by one, by 5s, or by 15s) through adding seven groups of 30 (and an extra 15) or by grouping by rows (adding five 45s) or grouping by columns (adding three 75s) to multiplying (15 x 15 or 15 squared, 45 x 5, or 75 x 3). Teachers build on these strategies by scaffolding a "math congress" (Fosnot, 1989), in the course of which they stress connections among solutions and explore the commutativity, associativity, and distributivity of multiplication within an array model.

Figure 2. Books: An advertisement found in a New York City tabloid

Could there really be 2 million books in eight miles of shelves (see Figure 2)? We presented this problem to the inservice teachers who participated in the Mathematics in the City Summer Institutes (Zolkower, 1998). Some teachers proceeded experimentally and from small to big—feet to miles—with a starting point of 12 books per foot of shelf space:

books	12	24	60	60,000	2,400	96	960	62,400	63,360	
feet	1	2	5	5,000	200	8	80	5,200	5,280	(1 mile)

books	64,000	128,000	256,000	512,000	*only a bit more than half a million books*
miles	1	2	4	8	

Other teachers worked in a reductio ad absurdum fashion and from big to small—miles to feet—taking as the starting point the advertiser's claim:

books	2 million	250,000	25,000	12,500	6,250	3,125	*about 50 books per foot of shelf space*
space	8 miles	1 mile (5,280 ft)	528	264	132	61	

So many books in such a small space! Each book would have to be 1/4 inch wide, which only works for magazines, journals, or children's books. But what if the books are stacked in two layers, either on top of or behind each other? As her calculations were leading her to believe that 2 million books could not fit in eight miles of shelves, a teacher commented, "We must be doing something wrong.
I know one of the owners. She wouldn't lie about it."

Reinventing Mathematics

From the perspective of RME, learning mathematics is defined not as the acquisition or appropriation of mathematics as a ready-made knowledge field, but as the process of reinventing mathematics. As Freudenthal argues, mathematical objects and procedures are truly appropriated when children—in collaboration with other children, and with the teacher's guidance—engage in mathematizing situations akin to those that historically gave rise to those concepts and procedures. In the classroom, the process of mathematizing is governed by the principle of guided reinvention, that is, "striking a subtle balance between the freedom of inventing and the force of guiding" (Freudenthal, 1991, p. 48).

Why reinvention? What the learners invent is new to them, yet it is, hopefully, well known to their teachers. Teachers can perform their guiding role only when they know themselves and they know ahead; that is, they must be able to anticipate students' inventions as well as most of their errors, confusions, and misunderstandings. The skillful teacher will manage investigations and conversations in such a way as to help students move slowly or make jumps—each at his or her own pace—from their invented, informal, often inefficient, and context-specific strategies, towards more conventional, formal, efficient, and widely applicable strategies.

What follows are two examples from the algebra and the fractions learning strands. The first example is a story problem: I went to the candy shop around my corner with $1 in my pocket. At this candy shop, which happens to be the smallest in the world, they sell only four different kinds of candies: packs of gum for 25¢, lollipops for 15¢, jawbreakers for 10¢, and kisses for 5¢. I left the store with no money and exactly seven candies in a brown bag. What could be in my bag?

In a second-grade class, children used numbers to indicate how many candies of each kind they had bought and how much money they had spent so far. They used symbols (e.g., drawings or letters) to represent the different kinds of candies, and they used operations such as adding and doubling to figure out their totals (see Figure 3). To help generate the need for symbolizing within the classroom community, the teacher may point to 60 + 25 + 10 + 5 = 100 (see Figure 4) and ask, "What do Janell and Eloise mean by this? Could we rewrite this number sentence so that everybody would understand it?" As for the total number of possible combinations, the road from a trial-and-error approach that allows students to find one or more combinations of seven candies for $1 without certainty that these are all there could be, to the more or less explicit use of the exchange model—as Janell and Eloise do, which is to start with two lollipops, then three, then four, and then six and, in each case, spend the rest of the money on other candies; or exchange two kisses for one jawbreaker, three kisses for one lollipop, five kisses for one pack

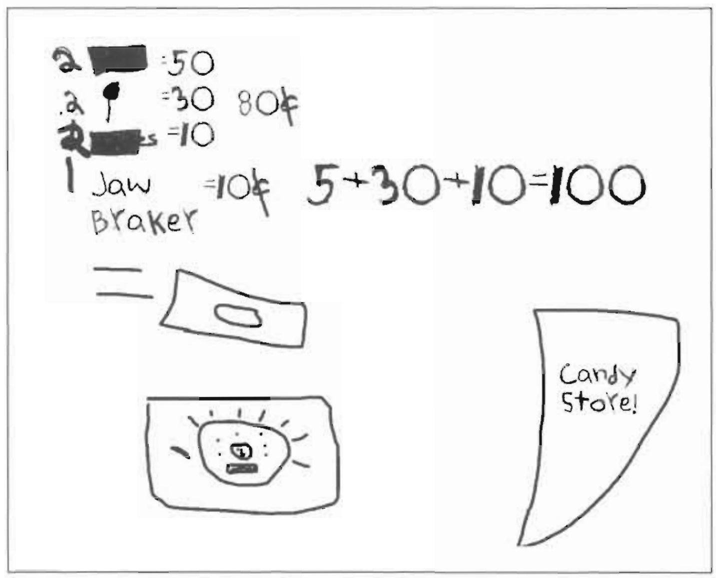

Figure 3. Briele and Alexis

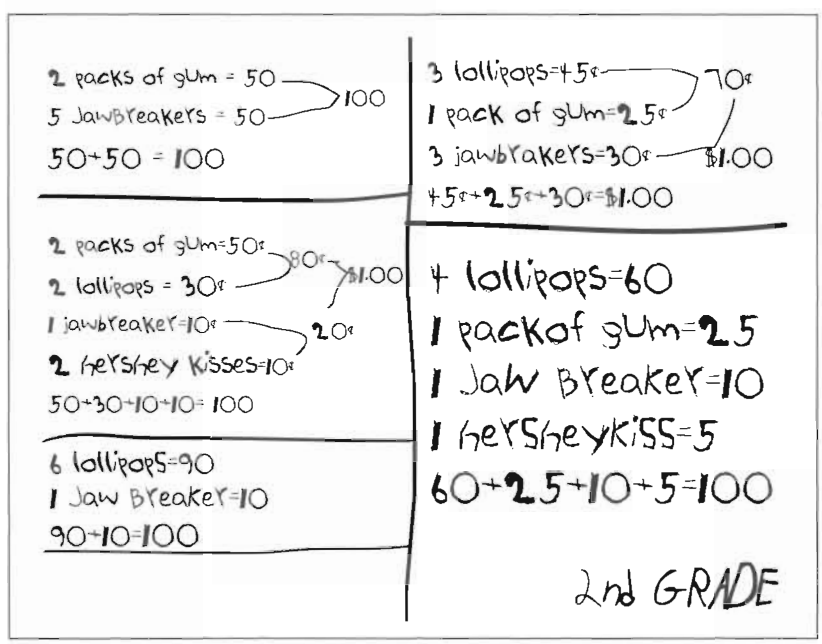

Figure 4. Janell and Eloise

of gum, and so on—may be described as mathematizing at higher and higher levels.

If children are to be guided to reinvent fractions, instruction cannot begin with fraction as a ready-made object (e.g., the denominator tells us in how many parts the whole is divided, and the numerator tells us how many parts we take). Instead, following Streefland (1991), fair sharing and fair distribution situations are introduced from the start. This allows for the mental-object fraction, in its interpretation as ratio, to emerge as a result of fractioning the objects to be shared (e.g., chocolate bars, pizzas, pancakes), examining the fairness of the distributions, comparing different distributions, and, eventually, finding formal names for "the tiny pieces" and the "small halves."

The starting point may be a situation where six children share five chocolate bars (Bidwell, 1982). Following is the work of third-grade students.

Anthony breaks three bars in half and two bars in six parts. Using arrows to deal the portions to the six children at the table, he writes, "each one gets one half and two small pieces." Whereas Brittany divides three of the bars in halves and the remaining two in thirds with no further commentary (see Figure 5), Hannah breaks every chocolate bar in six parts and concludes "five each" (see Figure 6). Athena breaks the five chocolates so that, as she explains, "each kid gets one half, a small piece, and a tiny piece" (see Figure 7). Rachelle and Myles proceed just like Brittany, but, after giving the children their two portions, each "half pese" becomes a whole ("now a hole") (see Figure 8). The teacher comments, "So, it looks like finally everybody got to eat a whole bar!" Rachelle replies, "No, that can't be. There isn't enough!"

Yet, as we all know, even in clear-cut situations such as this one, students may object to evenly fractioning the chocolate bars. "I'd bring another bar from the supermarket," proposes Yudalitza. Inventing names for the six chocolate sharers, Brian suggests, "Nancy can give a piece to Tommy." In response to the question of whether that would be fair, Brian says, "Yes, because she's sitting right next to him." It is up to the teacher to anticipate

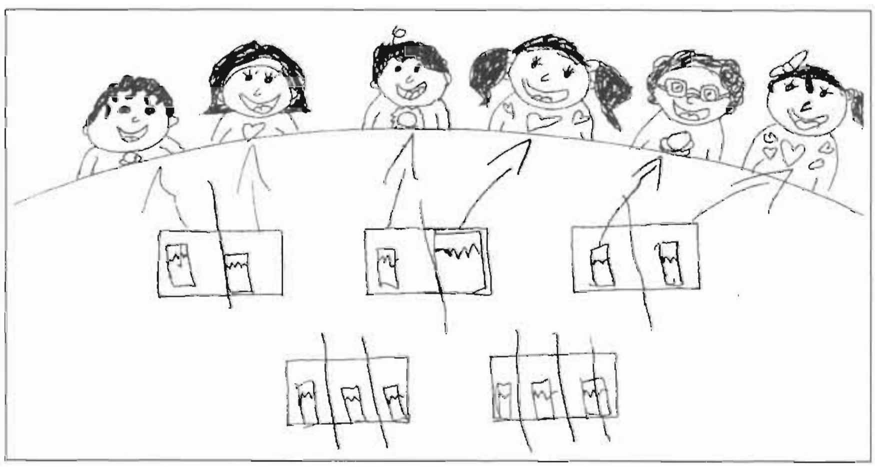

Figure 5. Brittany

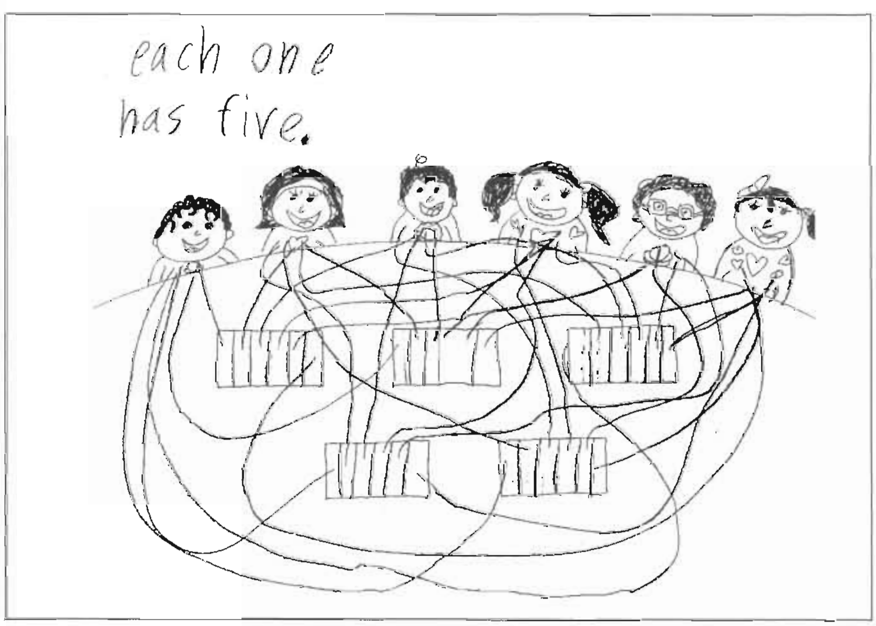

Figure 6. Hannah

as well as make room for these "misinterpretations" by making explicit the assumptions regarding the fair-sharing context.

Within the same fair-sharing situation (i.e., children, tables, chocolate bars), the teacher may propose three new scenarios: (1) a table where eight children share five chocolate bars; (2) another table where six children share four bars; and (3) another one where eight children share four bars (see Figure 9). If at stake is not what are the portions (described in fractional terms) at each table but, rather, at which of the four tables do children get to eat the most chocolate, most of the comparing could be done without actually doing the distributions!

Now, five bars for six children are certainly better than five bars for eight children. All that is left to compare is four bars for six children versus five bars for eight children. Distributing "a la Brittany" (halving) will lead, respectively, to 1/2 + 1/6 and 1/2 + 1/8; since 1/6 is bigger than 1/8, the first table is better off than the second one. Alternatively, one may argue that in the second situation, there are two more children than in the first, but only one more bar; therefore, the portions will be smaller.

Realistic Contexts

For mathematizing to occur, instruction ought to start not from ready-made formal systems, algorithms, structural games, or embodiments of mathematics in

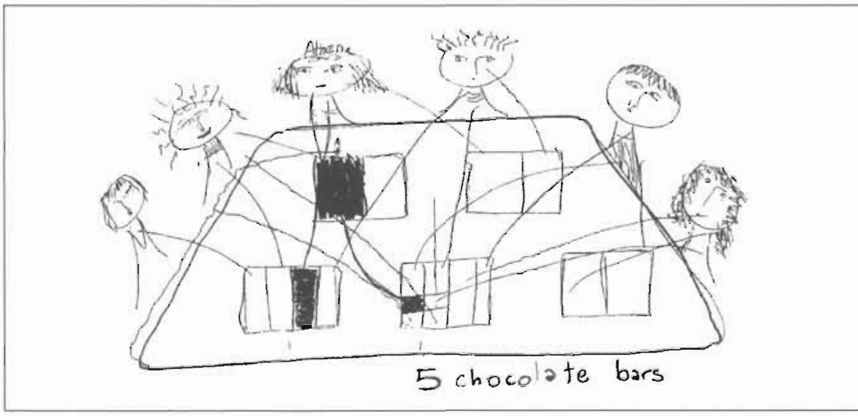

Figure 7. Athena

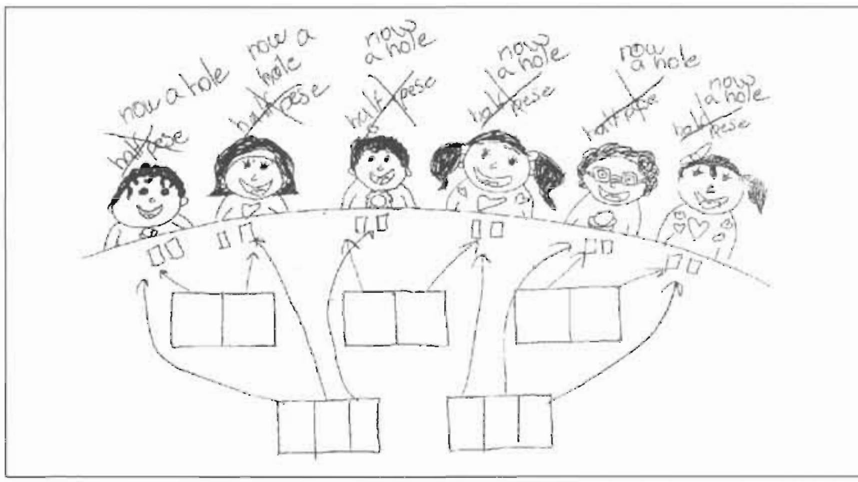

Figure 8. Rachelle and Myles

5 bars 6 children	4 bars *fewer bars, same number of kids: thus, 5 for 6 is better than 4 for 6* 6 children
4 bars *half a bar for each* 8 children	5 bars *more than half for each; thus 5 for 8 is better than 4 for 8* 8 children

Figure 9. Sharing Chocolates

concrete materials, but from realistic contexts—fragments of reality that beg to be modeled by mathematical means. Unfortunately, the expression "realistic contexts" is often misread as "real-life" situations. In Dutch, *zich realiseren* means "to realize in the sense of to picture or imagine something concretely" (van den Heuvel-Panhuizen, 1996). A realistic context may be a fictional one, as long as it is one that children may experience as real, that is, a situation within which they may think and act.

Consider, for example, the following situation, hereby presented to a group of third graders.

The Polar Bear: How many children together weigh as much as a 1,000-pound polar bear (van den Heuvel-Panhuizen, 1996)?

Latesha starts with her own weight ("I weigh 55") and then adds up the weight of other children in the class (see Figure 10). Luisa also uses the weight of her classmates, but she rounds these numbers up or down to make them "nicer to add." The first seven children together weigh 360 pounds. Another group of eight children contributes 410 pounds. The weight of four more kids is added to 770 pounds to reach the polar bear's weight. Luisa finds a way to reach exactly 1,000 pounds with 19 children (see Figure 11). Other students find out how many weights (within a range of 50 to 90 pounds) add up to 500, and then double that amount. Finally, others seem ready to work with the weight of an average child (e.g., Jeremiah's "50 x 20 = 1,000. It's 20 kids."). Nicole also starts with her own weight (68 pounds) (see Figure 12). After two trials, first with 34 children ("too much") and then with 14 children ("not enough"), she finds that 15 children together, ten of them weighing 67 pounds and the other five weighing 66 pounds, balance a 1,000-pound polar bear. And, as to Jeremiah's solution, Nicole objects, saying, "Kids don't all weigh the same."

Here is another imaginable situation:

A Human Pyramid: How many children are needed to make a pyramid as high as a 110-meter tower (see Figure 13)? (Janssen, van der Geest, & Raeven, 1985)

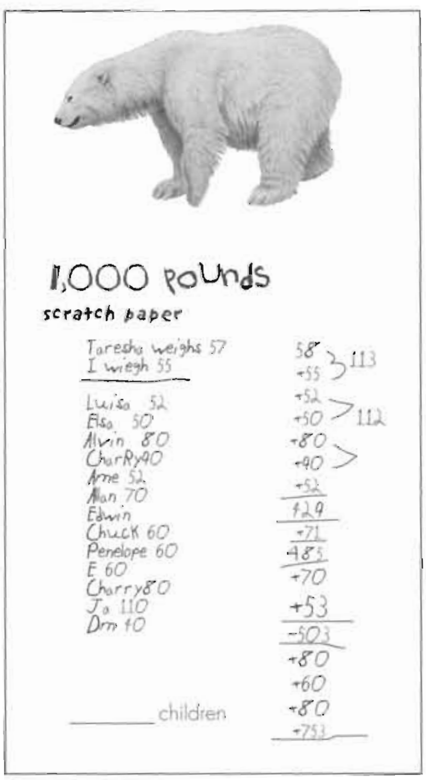

Figure 10. Latesha

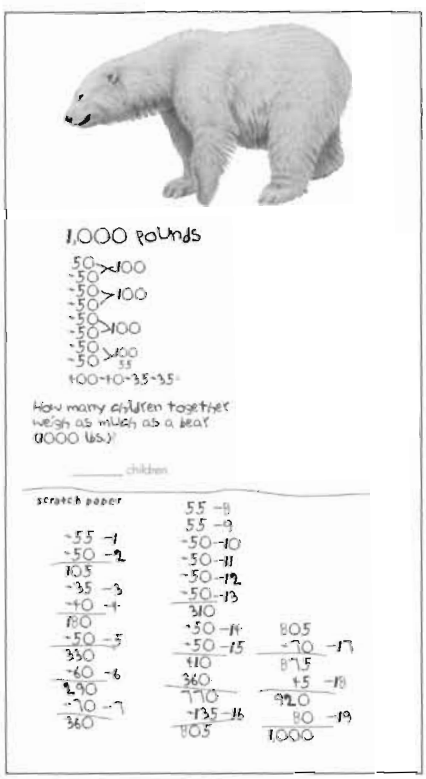

Figure 11. Luisa

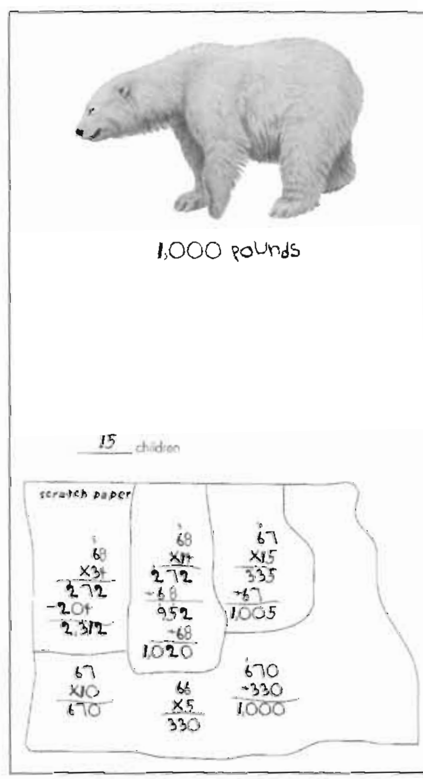

Figure 12. Nicole

Sixth-grader Cheng immediately puts himself in the situation: "My h[e]ight is 1.4 meter, but next person gonna stand on my shoulder. So it will be 1 meter of me." (See Figure 14.) He recalls an analogous situation where a four-cubes-high pyramid had four cubes on the bottom row. "I know the build[ing] is 110, so I need 110 people first. . . . The s[e]cond one [row] is 109 [people]. . . . So, then just keep on and on." Pairing up the extremes of the series 1 to 110, he makes the following list of sums: 110 + 1 = 111, 109 + 2 = 111, 108 + 3 = 111. "[I] keep on and on." He knows that there will be 55 sums because "110 ÷ by 2 = 55 . . . add all the fifty-five 111 together: 111 x 55 = 6,105. So, there will be 6,105 of me! Wow, that is alots 'me'!"

For contexts to serve not merely as applications of already-taught procedures but as starting points for mathematizing, they need to be more than camouflaged bare problems, as in most of the contrived word problems that characterize traditional mathematics instruction (Lave, 1992). As Freudenthal reminds us, "Context is not merely a garment clothing nude mathematics, and mathematizing is quite another thing than simply unbuttoning this garment" (1991, p. 75). Research evidence continues to grow about the extent to which instructional programs that rely solely on stereotyped word problems prevent students from developing the ability to put mathematics to use in modeling

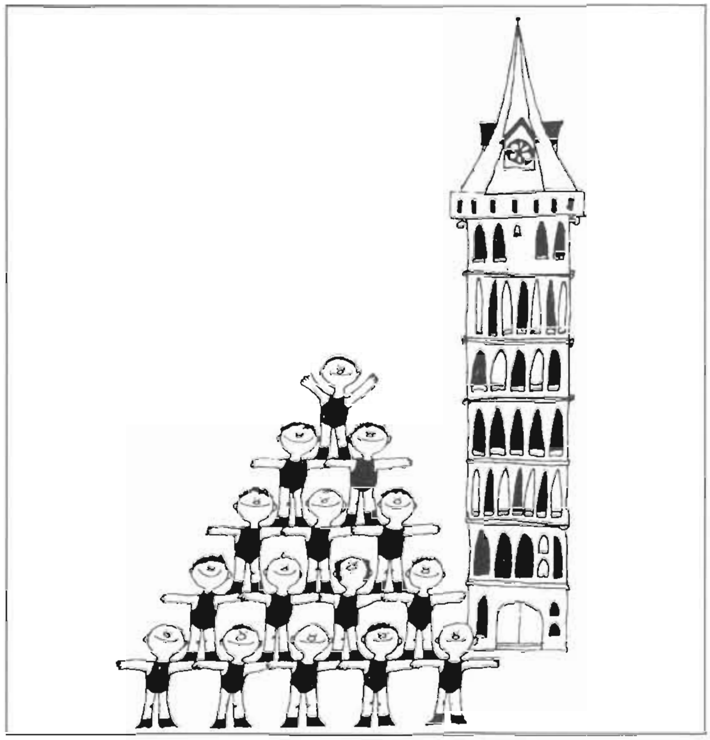

Figure 13. Human Pyramid

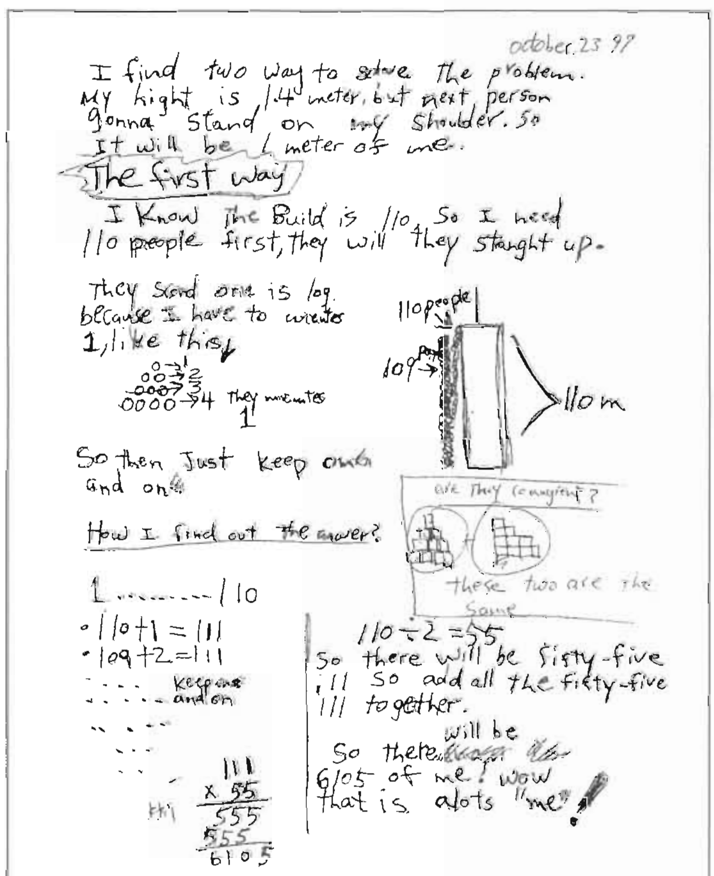

Figure 14. Cheng

real-life situations (De Corte & Verschaffel, 1989; Greer, 1993; Verschaffel & De Corte, 1997). Verschaffel and his colleagues have extensively documented the extent to which, after many years of apprenticeship in school mathematics, students become skillful at playing the word-problem language game. Among the implicit rules of this game is the leaving out of all assumptions about real life and the suspension of common sense, including, most conspicuously, money sense and the ability for mental computation.[1]

The argument for realistic contexts should not be forwarded solely in terms of motivation. . . . Neither should [it] . . . be forwarded only from the point of view of applications.

Realistic contexts allow for posing meaningful questions, formulating truly open-ended problems, and pursuing worthwhile investigations. Yet, where do these realistic contexts come from? We may find them in familiar school and everyday-life artifacts and situations, such as the following:

- open and closed necklaces with a 5- or a 10-structure for counting and moving beyond counting (More black beads or more white beads?) (Gravemeijer, 1994);
- using the rekenrek, an arithmetic rack modeled after a double-decker bus, with a 5- ,10- , 20-structure for addition and subtraction up to 20 (Gravemeijer, 1994);
- exploring the city-bus context, where addition and subtraction are modeled, respectively, by people getting on and off the buses (van den Brink, 1984; van Galen, Gravemeijer, Kraemer, Meeuwisse, & Vermeulen, 1995);
- reading a book (How many more pages until we finish it?);
- figuring out how much milk and cookies are needed for snack time;
- planning a school trip (How many buses are needed? How many tables at the picnic resort? How many subs should be ordered?);
- estimating the seating capacity of the school auditorium (Is there enough room for 700 people to sit?);
- paying for the bus fare (How many different coin combinations are possible?);
- the number-line model as a time line (How old will you be in the year 2012? How many minutes to the year 2001?);
- figuring out whether it is possible for the entire world population to join a birthday celebration in Rhode Island;
- calculating whether or not 1 million sheets of paper (8 1/2 by 11 inches) are sufficient for covering the entire surface of Central Park;
- estimating the cost in raw materials of making a T-shirt out of paper clips (a box of 350 paper clips costs $1.49);
- building a small-scale model of the classroom;
- cutting as many bookmarks as possible out of an expensive rectangular piece of paper;

and so on.

In the Netherlands, realistic contexts are designed by teams of curriculum developers and teachers in developmental research cycles where these contexts are first tried out in teaching experiments and then modified in light of the outcome of such experiments (Freudenthal, 1991; Gravemeijer, 1994). In developing these contexts, designers have in mind not only the theoretical learning line of the strand in question—concepts, models, and strategies—but also the actual learning trajectories of the students for which the materials are designed. In Mathematics in the City, we have been working more informally, designing our own contexts generally as part of the teacher/co-teacher joint lesson planning. At the same time, we have adapted materials from *Rekenen and Wiskunde* (van Galen, Gravemeijer, Kraemer, Meeuwisse, & Vermeulen, 1995) and from *Mathematics in Con-*

text: A Connected Curriculum for Grades 5–8 (National Center for Research in Mathematics Education and the Freudenthal Institute, 1988).

Conclusion

The argument for realistic contexts should not be forwarded solely in terms of motivation. Looking at some of the (old and new) curriculum packages, one would think that mathematics may be found only in bake and t-shirt sales, jumping-jack experiments, school calendars, card and board games, computer microworlds, baseball scores, and M & Ms. If schooling has an educational role to perform, it is fundamentally in the sense of stimulating in children an interest for what is not familiar, what is foreign, what is far away; a curiosity about the world in all its vastness and complexity; and the encouragement to imagine it as other than what it is. Neither should the argument for realistic contexts be forwarded only from the point of view of applications. One does not learn to mathematize by first encountering mathematics in camouflaged situations and then applying it to reality. As Keitel (1993) reminds us, such an approach does little to develop in students the ability to decipher the mathematics that is becoming increasingly invisible in our technologically mediated social world.[2] Shouldn't this, after all, be the ultimate aim of mathematics education? ❐

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For Further Reading

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Footnotes

[1] In my Ph.D. thesis (Zolkower, 1997), I note that a group of recent immigrant Spanish-speaking fourth-grade students, developed—as a survival problem-solving strategy in light of their difficulties in reading English—the disposition to cut through the noise when working on word problems, even in those cases of word and story problems designed with a multicultural intent.

[2] Keitel (1993) notes the gap between the growing objective importance of mathematics in society and the decreasing subjective importance of mathematics as it is taught in school. As she forcefully argues, while our technological and postindustrial society becomes more mathematized, citizens are becoming demathematized—alienated from an understanding of the means by which and the ways in which the social world is increasingly coded and managed by mathematics. Reminding us that mathematics education is one of those rare opportunities to experience and do explicit mathematics and modeling, Keitel echoes Davis's call (1989) for a shift in mathematics teaching from grammar to literature—an emphasis on alternative modeling activities that should lead to analyzing and judging applied mathematics critically.

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Using Pictures with Constraints to Develop Multiplication Strategies

Judit Kerekes and Catherine Twomey Fosnot

Focusing on beginning multiplication, Kerekes and Fosnot discuss the importance of disequilibrium in learning and show how constraints facilitate children's mathematical reconstruction and growth.

Although constructivism is a theory about how children learn, rather than a theory about how to teach, an analysis of it does suggest some principles of pedagogy that can be helpful to educators. For example, we know that strategies for multiplication computation are representative of the part/whole relations (i.e., the *big ideas* [Schifter & Fosnot, 1993] that learners have constructed) and that they cannot be taught via transmission because they require inferring, i.e., logical-mathematical knowledge (Piaget & Szeminska, 1952; Kamii, 1997). In fact, teaching procedures or algorithms with a pedagogy based on transmission, practice, and feedback strategies have been shown to create place-value errors and actually work against the development of number sense. Children who have been allowed to construct their own strategies for computation may make mistakes at times as well, but their mistakes are computation errors rather than place-value errors, and their answers are representative of good number sense (Kamii, 1998).

Constructivism also helps us understand the developmental nature of big ideas and recognize the important role of disequilibrium in learning, which, according to Piaget, arises from the recognition that one's strategy is insufficient or from the puzzlement when two ideas seem contradictory (Piaget, 1977). Teaching from this perspective, then, becomes a case of facilitating disequilibrium rather than of providing positive reinforcement. In multiplication, children often begin with inefficient strategies, such as skip counting or repeated addition. Only later do they develop more efficient strategies, such as doubling (e.g., calculating 4 x 8 by doubling 2 x 8 to get 16 + 16 = 32) or using tens, employing the distributive property (e.g., calculating 12 x 13 by doing [10 x 13] + [2 x 13]). This development of strategies has been referred to in the literature as *progressive schematization* (Dolk, Uittenbogaard, & Fosnot, 1996; Treffers, 1987).

The resulting question for educators is this: How best to facilitate this progression? Certainly, we need to use open-ended investigations and problems that allow for many entry levels and the learner's own construction of strategies. But we also need to consider how to stretch and challenge learners' initial strategies in order to facilitate the development of higher-level strategies. We need a safe, risk-supportive environment, but one in which learners are invited to consider and generate more efficient strategies than their initial construction. We need to support the development of natural pseudoconcepts, but work within the zone of proximal development towards the development of the scientific (Vygotsky, 1986).

The Role of Context

Working within the paradigm of Realistic Mathematics developed by the Freudenthal Institute in the Netherlands, several researchers have been looking at the role of context in mathematics teaching and learning.

Different contexts obviously can suggest different models of multiplication. For example, the problem *I have 12 boxes of pencils with 15 pencils in each box; how many pencils in all?* suggests repeated addition, whereas the problem *A patio made of tiles has 12 rows with 15 tiles in each; how many total tiles?* suggests an array or area model, and the problem *I have 12 blouses, 15 pants; how many outfits?* suggests a tree or branching model. Different contexts can also challenge familiar strategies or elicit new ones. For example, asking children to figure out how many plums the grocer has in the box (see Figure 1) elicits most often either counting by ones or a repeated-addition strategy. In contrast, calculating how much the strawberries cost if they were $4 a quart (see Figure 2) presents nothing to be counted, and because doubling occurs in the picture, it is more likely that children will employ either a skip-counting strategy or a doubling strategy. Of course, children can use their fingers to count the $4 by ones repeatedly if they need to, so the safe environment with multiple entry levels is there. But the context is likely to stretch initial counters to give up this inefficient scheme and construct, instead, a multiplication strategy based on repeated addition or doubling. The fact that the strawberry problem does not provide objects to be counted by ones is its constraint.

Another example of a pictorial context with a constraint is the patio problem (see Figure 3). How many tiles are in the patios? Here, the chaise lounge and the umbrella block some of the tiles, once again imposing a constraint to a counting strategy and possibly engendering the use of the distributive property.

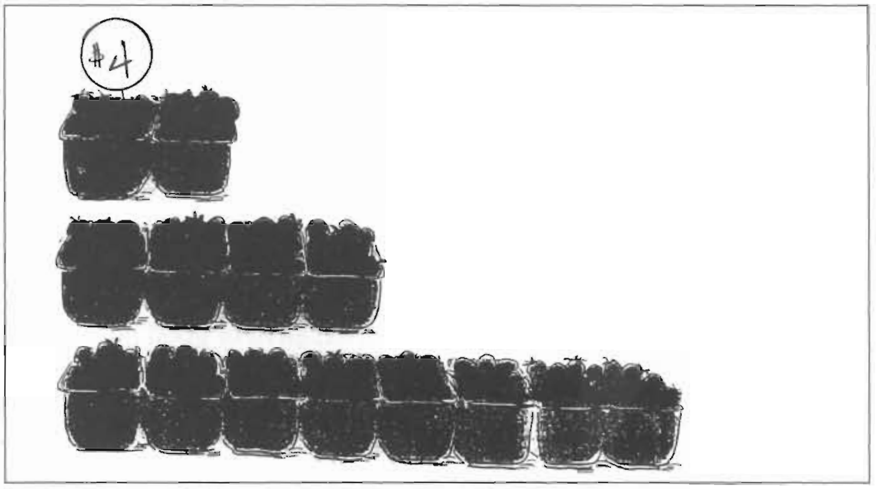

Figure 2.

It is our belief that such constraints can be powerful inducers of disequilibrium, while maintaining a safe, risk-supportive, open environment. The problems are open, yet the constraints may facilitate devel-

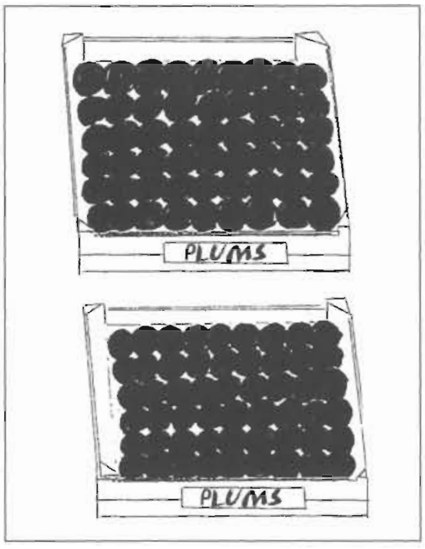

Figure 1.

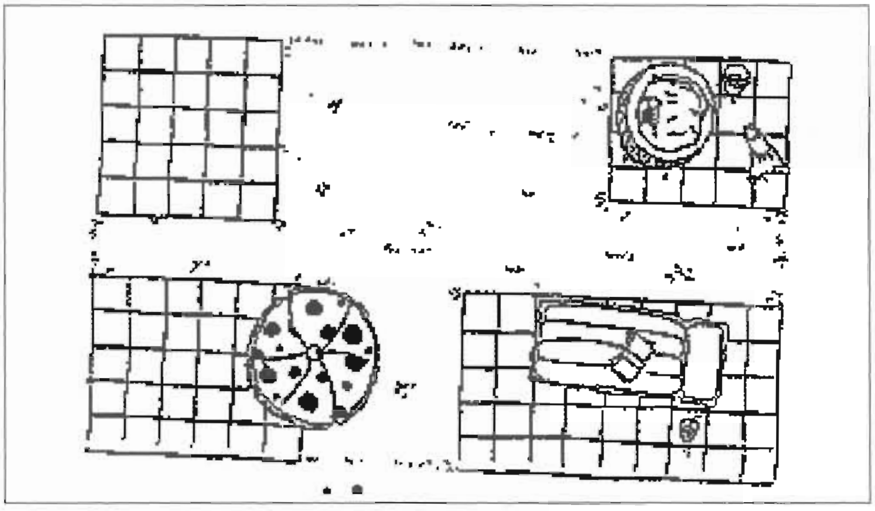

Figure 3.

opment. As part of the work we have been doing in Mathematics in the City (a National Science Foundation-funded collaborative in-service project with the Freudenthal Institute), we have been using pictures with built-in constraints to develop multiplication strategies and big ideas. Our pictures come from curriculum materials developed by the Freudenthal Institute (van Galen, Gravemeijer, Kraemer, Meeuwisse, & Vermeulen, 1995). They have been used previously in Holland, but not in American schools. The remainder of this article will describe children's work in a third-grade classroom in New York City as they began to study multiplication.

Children's Work

We began by asking the children to figure out how many plums, lemons, apples, tomatoes, etc., a grocer had on display. Children were shown pictures of different arrays of fruits in boxes, similar to the plums in Figure 1, and told a story about the grocer. Except for two children who knew the multiplication fact 6 x 9 = 54 and could use it in this context (having probably learned it at home), all the children counted by ones. With smaller arrays of lemons and tomatoes (3 x 3 or 4 x 3), some children used skip counting. Here, the multiple was easier to handle with skip counting by fours or threes, whereas the plums simply produced counting by ones.

The second series of pictures we used depicted curtains and window shades with designs (see Figure 4). The children were told a story of how the teacher awoke from a dream and looked at her bedroom windows, puzzled as to how many designs were on the shades and curtains. These pictures have constraints. In two of the pictures, the shades are not all the way down, so counting by ones can only be done if one counts the half-pulled shades twice. With the curtains, one

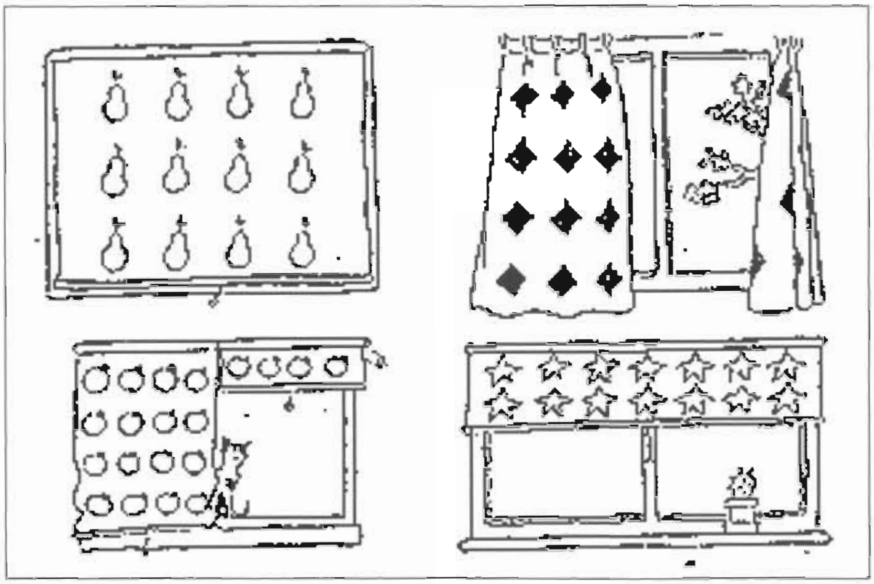

Figure 4.

curtain is purposefully pulled aside. This series of pictures is designed to promote doubling. Of course, if children count by ones, their strategy is accepted and discussed, but the constraint is likely to elicit the inefficiency of this approach. That is, in fact, what happened. With this series, children did not count by ones: five used skip counting (e.g., 3, 6, 9, 12, 15, 18, 21, 24), two used repeated addition (they actually wrote 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3 = 24), eleven used doubling (they doubled 4 x 3), and four responses could not be coded. The teacher then facilitated a discussion on how the eight rows of three diamonds in the curtains could be figured out by calculating four rows and doubling it. She wrote the symbols to represent this idea in the following way: 8 x 3 = 2 x (4 x 3) = (4 x 3) + (4 x 3) = 24.

The third picture that we presented depicted a baker's dilemma. How many muffins does he have? How many did he have when all the trays were filled? How many has he sold? The muffins in the second and third tray are related to the amount in the first tray. Will children notice this? Will they construct the distributive property, seeing that 9 x 4 = (5 x 4) + (4 x 4)?

Jennifer still counts by ones,

ignoring the constraint (see Figure 5). Tyler also ignores the constraint, although he employs a slightly more efficient strategy than Jennifer (see Figure 6). He figures out the middle tray by skip counting by twos. However, this seems inefficient to him, and although he continues skip counting, this time he does it by tens. He makes a calculating error and gets 75, but his unitizing is solid, and one can see how he rethinks his grouping strategy towards greater efficiency. One does wonder, though, whether he thinks it is possible that both answers could be correct, 72 and 75. Brooklyn, on the other hand, begins by using repeated addition (see Figure 7). She solves the second and third trays by repeatedly adding fours, but when she gets to the first tray, she shifts her strategy to the distributive property. She describes the relationship between the trays and adds the second and third together to get the first. Other children also make use of this strategy. Jacob's work, for example, shows a solid understanding of the distributive property (see Figure 8). He writes, "This one [the middle tray] have 16 because the right one have 20 if I take away 4 it will be 16 [4 x 4 = (5 x 4) – 4]." And he calculates the first tray similarly: "There are 36. the last one help me because I plus 20 more [to the 16 in the middle tray] and I got 36." Although the picture is not designed to elicit doubling and halving, some children do use this strategy.

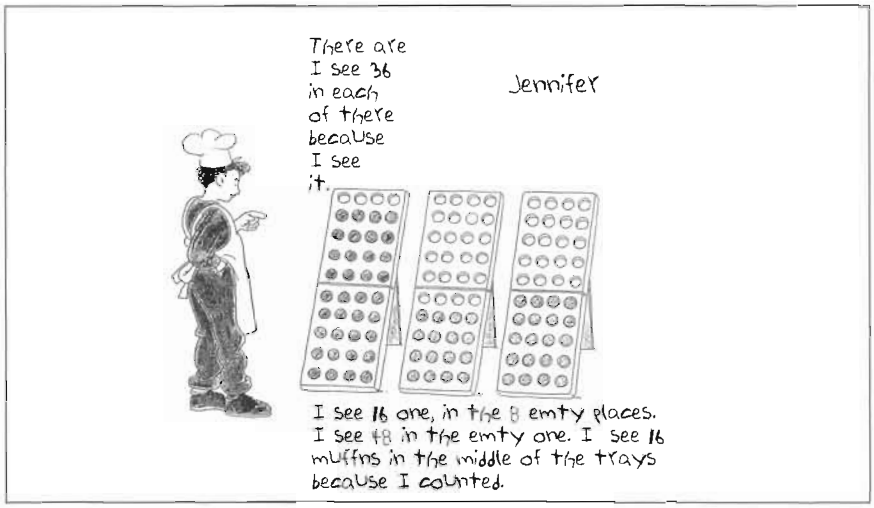

Figure 5.

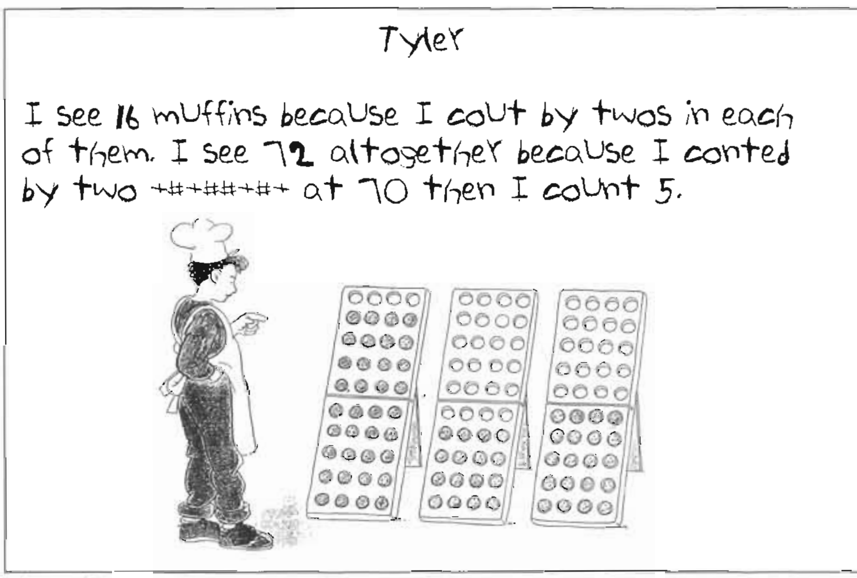

Figure 6.

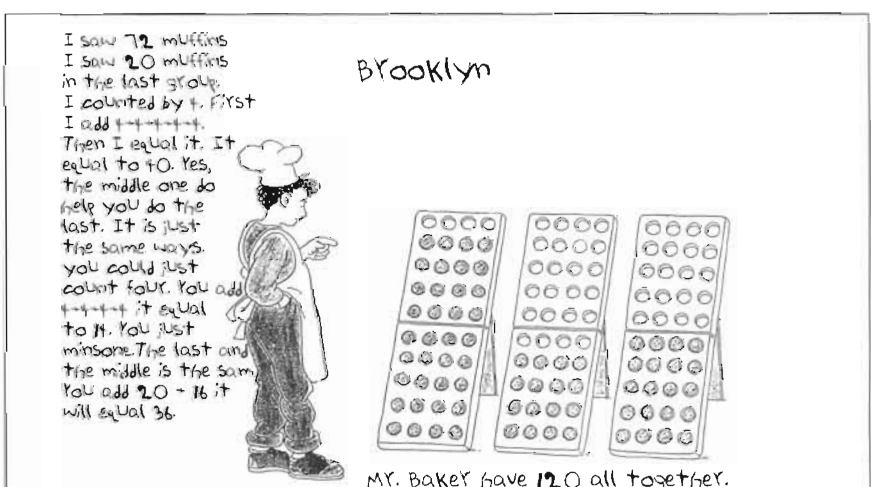

Figure 7.

Christina figures out that 4 x 4 = 2 x 8 and that 5 x 4 = 8 + 8 + 4 (see Figure 9). She solves the first tray by turning 9 x 4 into (4 x 4) + (4 x 4) + 4.

Each of these pictures gives children the chance to construct their own free production, but the interesting issue for the educator regarding the role of context is whether children use their own familiar constructions across contexts, or whether they indeed change their strategy, constructing a new one in response to the constraints. In the baker problem, where the constraint suggests the distributive property, 8.7% (2 out of 23) of the children counted by ones, 13.0% (3 out of 23) employed skip counting, 13.0% (3 out of 23) utilized repeated addition, and 8.7% (2 out of 23), doubling and halving. Two samples could not be coded (8.7%). The remaining 11 children (48%) used a form of the distributive property and described the relationships between the trays. These responses are remarkably different than the range of strategies used for the bedroom window dilemma, a problem designed to elicit doubling. Here, 5 out of 22 (23%) used skip counting, and 2 out of 22 (9%) used repeated addition. Once again, a few samples were uncodable—4 out of 22 (18%). But with this problem, no child used the distributive property, and 50% (11 out of 22) used doubling. ***Note.*** The total number of children changed from 23 to 22 because one child was absent the

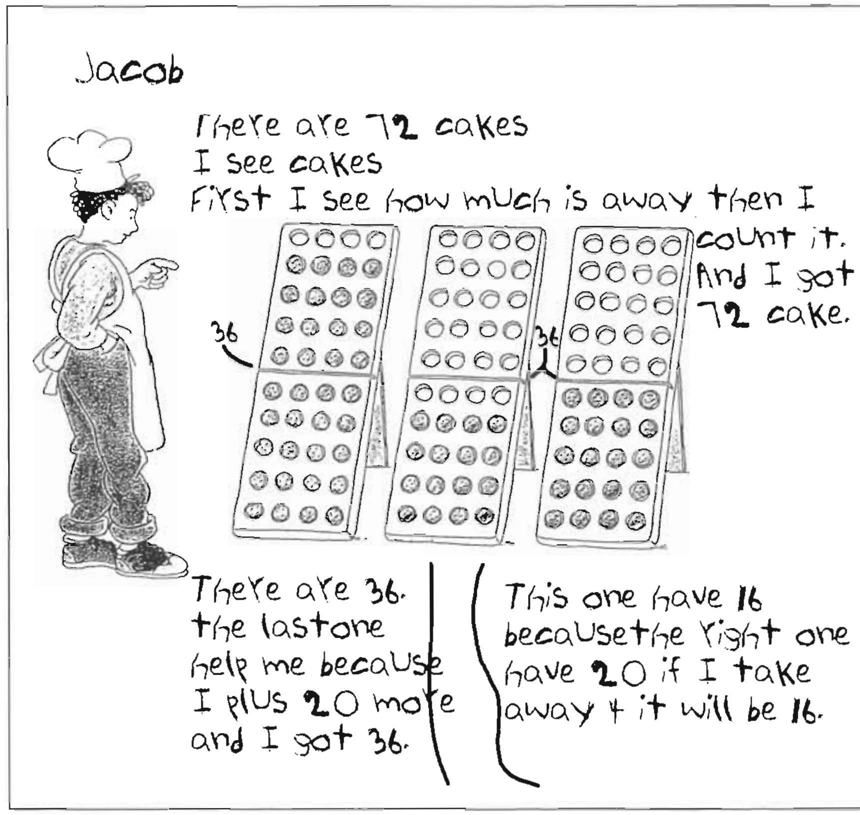

Figure 8.

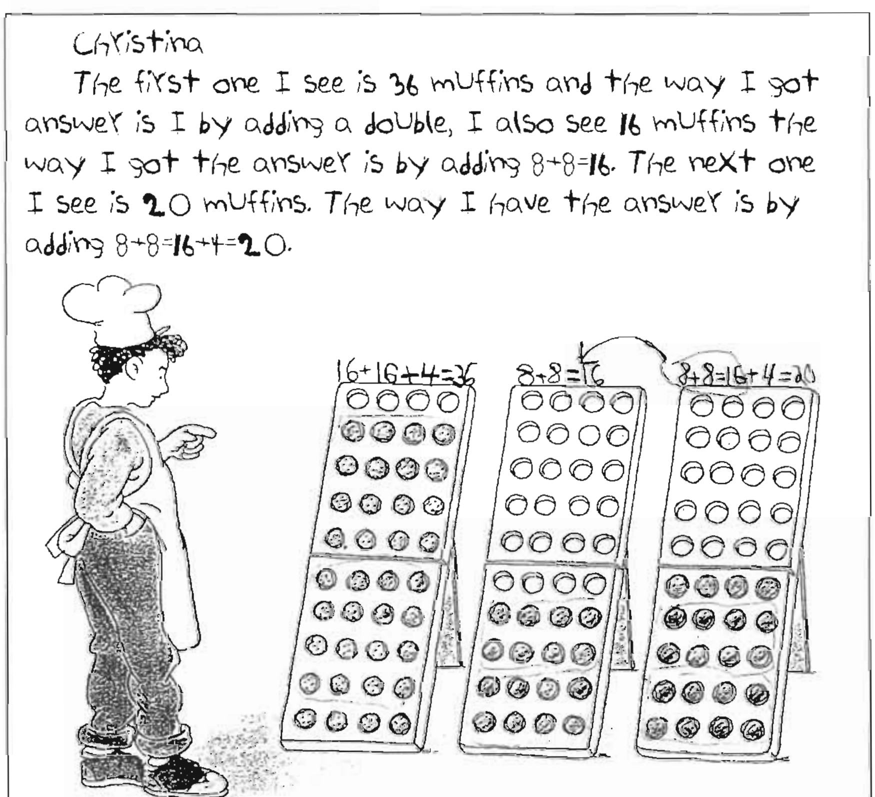

Figure 9.

day the curtain problem was posed.

Discussion

If children indeed change their strategies in relation to the constraints in contexts, then designing investigations with such constraints in mind is a powerful pedagogical tool for the educator trying to elicit big ideas or stretch children's initial strategies towards more efficient ones. By keeping the problems open, we invite children to solve them at their own developmental level, and we support their spontaneous, natural constructions. The constraints within this open structure though may serve as inducers to reconstructing. They may encourage new strategies or provide difficulties for initial strategies, thereby facilitating disequilibrium. In this way, the constraints stretch and challenge strategies and enable progressive schematization. They also bring wonderful teaching moments to the surface for further inquiry: for example, exploring why the distributive property works and trying it out with larger numbers such as 12 x 13, investigating the different ways the numbers could be broken up and the ways in which the parts are connected to the whole.

By working with children in this fashion, we honor their initial constructions, but we also make the role of facilitator meaningful. We encourage children to agree and/or disagree with each other and to examine the efficiency and elegance in each other's strategy. We stretch and challenge their initial strategies and encourage the development of higher-level ones. This process honors their thinking, but works with them in their zone of proximal development. ❐

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Number Strings: Developing Computational Efficiency in a Constructivist Classroom

Jennifer DiBrienza and Gary Shevell

Children develop stronger number sense if allowed to explore strategies when computing, instead of being tied down to rigid procedures, such as algorithms. Guided by this belief, DiBrienza and Shevell demonstrate the powerful role of number strings in promoting computational efficiency.

One of the main criticisms and concerns parents and administrators have about constructivist mathematics teaching is that children do not learn to compute quickly and accurately. Because of this misperception, teachers are under pressure to teach standard algorithms. Much of Constance Kamii's work shows that this approach is misguided and may, in fact, be detrimental to children's understandings about number (Kamii, 1998).

Children should be allowed to come up with their own strategies for computation. Yet in many instances, the strategies that children invent, while they make sense to the student and may be mathematically correct, are cumbersome and inefficient. What can teachers do to be sure their students are developing a repertoire of efficient computation strategies when working with numbers? As educators, we must provide opportunities for children to hone and develop big ideas and to strive for efficiency and elegance in their strategies. One such opportunity involves mental-math activities using *number strings.*

What Is a Number String?

A number string is a series of related but bare (devoid of context) computation problems that are specifically designed to elicit quick, efficient, and reliable strategies for computation from students. The problems are written horizontally, not vertically. When problems are written this way, they do not encourage any one particular strategy. Writing problems vertically, on the other hand, inherently suggests a place-value splitting strategy.

Number strings give students a chance to notice patterns and hone their computational skills in a constructivist way. The goal is for children not to be bound to a rigid procedure such as an algorithm that is used regardless of the problem, but rather, to look to the numbers to decide which strategy to use. After all, this is what mathematicians do; they look for and create elegant solutions.

Take the following problem:

4,017 – 3,998.

When students solve this using the traditional algorithm, they must "borrow" a 1 from the tens column because 8 is larger than 7. Next, they must "borrow" a 1 from the hundreds column; however, that is not possible, so they must change the 4 from the thousands column into a 3, give the extra thousand to the hundreds column, change the hundreds column from a 10 to a 9, give the extra hundred to the tens column and finally subtract each column. Then—and only if the student has done every step correctly—will she have the correct answer. Moreover, if she made a mistake, the student has no way to check except to repeat the algorithm or perform an addition algorithm to check her subtraction algorithm. There is no use of number sense.

A child from a constructivist classroom who has been allowed to invent procedures might say, "4,000 take away 3,000 is 1,000. 1,000 take away 900 is 100. 100 take away 90 is 10. 10 take away 8 is 2, plus 17 is 19, so the answer is 19." (See Figure 1.)

$$
\begin{array}{r}
4{,}017 \\
-\ 3{,}998 \\
\hline
1{,}000 \\
-\ 900 \\
\hline
100 \\
-\ 90 \\
\hline
10 \\
-\ 8 \\
\hline
2 \\
+\ 17 \\
\hline
19
\end{array}
$$

Figure 1.

The student first looked to the numbers to decide which strategy would work best and then proceeded. This child has some number sense, but is this how we want children to solve problems like this?

A child from a constructivist classroom who has consistently worked with number strings might use a constant-difference strategy: add 2 to both numbers, making the problem

4,019 – 4,000.

This answer also is 19. This child has exhibited true number sense. He did not jump right in and perform an algorithm, whether standard or invented. Nor did he perform an invented strategy that is inefficient for these numbers. Rather, he first looked to the numbers to decide which strategy would work best and then proceeded. It is clear that this child has some deep understandings about subtraction. He is able to treat the numbers as whole, without breaking them into unnecessary parts. Further, he understands the value of landmark numbers and is capable of using them to make this problem friendlier. Finally, he understands subtraction as difference and that for these numbers, adding two to each, maintaining the difference, is a more efficient strategy for subtracting than removing numbers.

All of these ideas can be explored using number strings. Figure 2 is an example of a string that is likely to elicit a constant-difference strategy.

150 – 75
151 – 76
149 – 74

294 – 100
291 – 97
301 – 107

Figure 2.

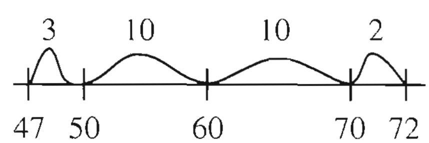
Children see that the first three answers are the same and then investigate how they are related. In the next three problems, the situation repeats itself, giving students an opportunity to explore further. Eventually, when they understand the strategy, they add it to their repertoire.

When doing a string with a group of students, the teacher places a single problem on the board horizontally. The teacher then gives the students think time to mentally solve the problem and prepare to verbalize what they did. As children share their ideas, the facilitator visually represents what they say. Students hear and see representations of their peers' strategies, and they can discuss the variety of approaches.

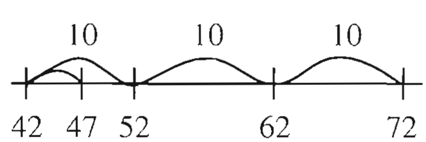
For example, the teacher may write this problem on the board:

72 – 25.

One student might say, "First I took 2 away from the 72 to get to 70. Then I jumped back 10 to 60. Then I jumped back another 10 to 50. I still had 3 more to take away. 50 minus 3 is 47." The teacher may draw on the board:



Another student may add, "I did it differently. I started at 72, jumped back three 10s to 42, and then added 5 back on, so the answer is 47." The teacher draws on the board:



After a few different strategies are shared, discussed, and clarified, the next problem in the string is introduced with the same procedure. This process continues throughout the string, while the facilitator capitalizes on opportunities to further student thinking.

To be effective, number strings need to be explored on a consistent basis. It takes time and exploration to construct a deep understanding of any one strategy, and there are many strategies worth exploring. In order for students to truly look to the numbers, they must explore all of these strategies in conjunction with one another. If they are only able to explore certain big ideas, the related strategies risk becoming algorithms themselves.

Only by doing string work regularly can students develop efficiency in their computation. *However, number strings are not a substitute for hands-on investigation and exploration.* Strings can cause students to raise questions around number, but children will not construct the mathematical big ideas embedded in number strings unless these properties of number are also investigated in hands-on, child-directed mathematical investigation.

Addition and Subtraction Strings

The following are some of the *addition and subtraction* big ideas that our students have constructed and explored through string work.

• *Keeping the first number whole and adding or subtracting by moving to the nearest 10 (or 100) or making jumps of 10 (or 100)*
Through various investigations and games, students begin to recognize the importance of 10 as a landmark number. Figures 3 and 4 provide examples of strings that can be explored in conjunction with this concept.

• *Counting up to subtract*
This is another important big idea for subtraction. After students discover, through context problems, games, and investigations, that it is possible to count up when subtracting, as well as to count backwards, the teacher can use strings to explore when it might make more sense to count up than to remove. Figure 5 is an example of a string that is designed to explore this idea.

Children working on this string might realize that for some of these problems, counting up to subtract is quite a task, while for the others, it is rather easy. The teacher can then facilitate a class conversation around why certain numbers beg for particular strategies.

Multiplication and Division Strings

The following are some of the big ideas through which we can investigate *multiplication and division.*

• *Doubling and halving*
As students work with arrays to explore multiplication, they begin to discover that by rearranging the array, the problem can be changed, yielding the same product. For example, if students are presented with 3 1/2 x 14,

Moving to the Nearest 10	
17 + 3	42 – 2
17 + 6	42 – 7
27 + 3	62 – 2
27 + 16	62 – 27
57 + 3	72 – 2
57 + 36	72 – 37

Figure 3.

Making Jumps of 10	
27 + 10	33 – 10
37 + 10	53 – 10
47 + 20	53 – 20
47 + 24	53 – 24
56 + 30	83 – 50
56 + 35	83 – 54

Figure 4.

101 – 97
101 – 6
153 – 145
153 – 14
513 – 489
513 – 24
1,003 – 992
1,003 – 27
4,017 – 3,998
4,017 – 78

Figure 5.

they can solve it by doubling the 3 1/2 and halving the 14, making the problem 7 x 7 (see Figure 6).

With continued string work, we see that the strategy can go beyond doubling and halving, as shown in Figure 7.

Here is a division example: 300/12.

If both numbers are cut into thirds, the problem becomes 100/4, as in Figure 8.

Figure 9 shows a division string that might bring up this strategy for investigation.

• *Using landmark numbers and using landmark numbers with compensation*

The distributive property of multiplication is another big idea around which we can explore multiplication and division. For example, the arrays in Figure 10 show how the distributive property can be used for double-digit multiplication.

Figure 11 shows multiplication and division strings that explore this idea.

The Role of Conversation

Student interaction and conversation around the strategies they use are crucial aspects of string work. During conversation, students are held accountable to try to make sense of each other's strategies and defend their own. Accountable talk seriously responds to and further develops what others in the group have said (Institute for Learning, LRDC,

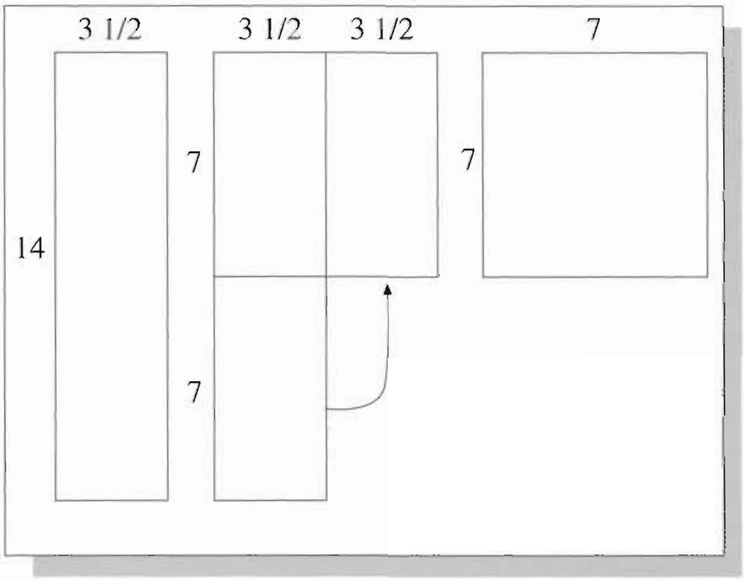


Figure 6.

3 x 6
3 x 12
6 x 12
3 x 24
9 x 8
6 x 24
12 x 12
4 x 36
2 x 18

Figure 7.

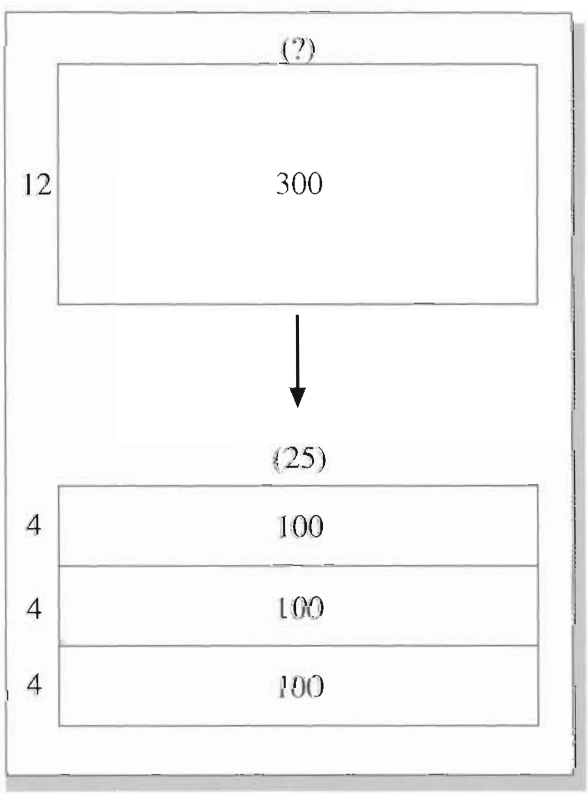


Figure 8.

16 / 4
32 / 4
64 / 8
32 / 8
32 / 16
64 / 16
128 / 32

Figure 9.

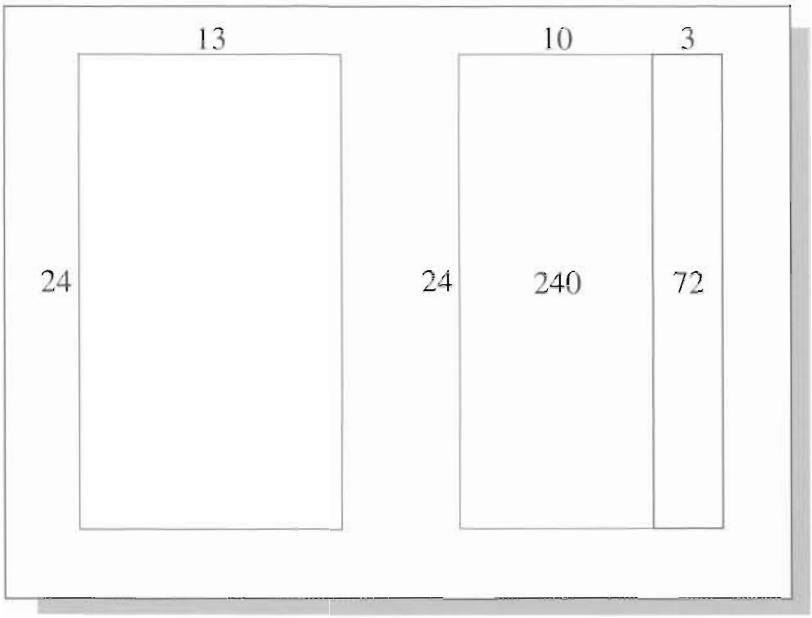


Figure 10.

10 x 10	100 / 4
1 x 10	36 / 4
11 x 10	136 / 4
11 x 3	144 / 12
11 x 13	48 / 12
12 x 10	192 / 12
12 x 14	143 / 13

Figure 11.

1997). By sharing their strategies, students are afforded opportunities to further their own understandings. String conversations may also provide opportunities to try other strategies, to explore why an approach works, and to debate about efficiency.

Conclusion

Mental math using number strings is a powerful way to focus conversation on computation strategies and to develop the eventual goal of number sense—number sense that is strong enough to enable students to look to the numbers before they decide on their strategy.

We need to teach math, of course, primarily through learner investigations, but mental math can be a powerful mini-lesson at the start of math workshop. Also, whenever a teacher has 15 minutes, she can use a number string. Morning meetings and/or transitions are excellent opportunities as well.

The more students work with strings, the more efficient their strategies will be. Children who are given opportunities to explore and construct strategies will derive aesthetic pleasure in playing with numbers and searching for elegant solutions. ❐

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Jennifer DiBrienza and **Gary Shevell** are affiliated with the Mathematics in the City project at the City College of New York.

Highlights from the 1999 ACT Annual...

Keynote Speakers:

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Participants enjoy two days of sharing, learning, and networking...

...Conference in St. Louis

ASSOCIATION for CONSTRUCTIVIST TEACHING

Annual Conference

October 19–20, 2000
W Atlanta at Perimeter Center
Atlanta, Georgia

The Board of Directors of the Association for Constructivist Teaching is pleased to announce that the 2000 conference will be held at the W Atlanta at Perimeter Center in Atlanta, Georgia, on October 19 and 20, 2000. Please note the call for proposals below.

CALL FOR PROPOSALS

APPLICATIONS OF CONSTRUCTIVISM FOR ALL LEARNERS

The Association invites proposals for workshops (1 1/2 hours in length) for the 2000 conference. We seek presentations regarding applications of Piaget's theory of constructivism to both general and special-needs populations. We also welcome research papers and symposia regarding implications of constructivist theory for educational practice.

Please write a descriptive statement of your session's purposes, activities, and intended audience. Limit your proposal to three pages, and attach it to the presenter information form. Include a brief overview of your current position and previous experience in education. Send your proposal to

Linda Kroll
Associate Professor, Department of Education
Mills College
5000 MacArthur Blvd.
Oakland, CA 94613-1301

For more information, contact Linda by phone at (510) 430-3161.

Proposals must be postmarked by May 20, 2000.

ACT Annual Conference 2000

Presenter Information and Audio-Visual Request Form

Please include information for all copresenters.

Session Title ______________________________

Presenter:

Name ______________________

Title & Affiliation ______________________

Address ______________________

City, State, Zip ______________________

Home Phone ______________________

Work Phone ______________________

E-mail ______________________

Summer Address ______________________

City, State, Zip ______________________

Summer Phone ______________________

Copresenter:

Name ______________________

Title & Affiliation ______________________

Address ______________________

City, State, Zip ______________________

Home Phone ______________________

Work Phone ______________________

E-mail ______________________

Summer Address ______________________

City, State, Zip ______________________

Summer Phone ______________________

Copresenter:

Name ______________________

Title & Affiliation ______________________

Address ______________________

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Home Phone ______________________

Work Phone ______________________

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I need the following audio-visual equipment:
please check appropriate boxes

❑ Overhead Projector & Screen
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❑ VCR/Monitor
❑ Other______________
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Please list any additional copresenters on a separate sheet.

Classified Ads

Have a job opening that you want to announce in *The Constructivist*? Send copy, with contact information, to Sukanya Dutta-White, Project Construct National Center, 27 S. Tenth Street, Suite 202, Columbia, MO 65201-5009; Phone: (800) 335-PCNC; E-mail: sukanya@projectconstruct.org

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Advertisements

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ASSOCIATION for CONSTRUCTIVIST TEACHING

Constructivist teaching provides a rich, problem-solving arena that encourages the learner's investigation, invention, and inference. The constructivist teacher values learner reflection, cognitive conflict, and peer interaction. ACT is a professional educational organization dedicated to fostering teacher development based on these principles.

Our Mission . . .

Is to enhance the growth of all educators and students through identification and dissemination of effective constructivist practices in both the professional cultures of teachers and the learning environments of children.

Membership . . .

Is open to anyone interested in the field of education including classroom teachers, administrators, supervisors, consultants, college and university personnel, students, and retired educators. Dues are $30 per year regular and $20 per year for students and retirees; the membership period runs from January through December.

ACT Goals

1. To provide increased and varied resources to an expanding membership.
2. To increase attendance at and participation in ACT's annual conference.
3. To publish effective and practical strategies for applying constructivism in the classroom through ACT's scholarly magazine, *The Constructivist*.
4. To provide a network through which teachers, researchers, speakers, and other professionals can support and extend each other's efforts to integrate Piaget's theory of learning into their classroom and within the context of federal, state, or local mandates.
5. To encourage members to contribute actively to the association's development and engage others in expanding the network of those who are willing to support each other's growth as constructivists.

Benefits of Membership

- *THE CONSTRUCTIVIST* . . . a scholarly magazine, published three times a year.
- ANNUAL CONFERENCE . . . discounted registration fee and early notice of call for presenters.
- AFFILIATION . . . with an association committed to supporting you.

Visit Our Web Site

http://www.users.interport.net/~roots/ACT.html

The Association for Constructivist Teaching

Membership Application

_____ New

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Name: ______________________ Title: ______________________

( ) Business Address: ______________________ ( ) Home Address: ______________________

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Please check the address and phone to which we should address our contacts.

Annual* Dues: January–December

$30.00 [Regular]

$20.00 [Students & Retirees]

Please make your check payable to the Association for Constructivist Teaching, c/o Brenda Fyfe, School of Education, Webster University, 470 East Lockwood Avenue, St. Louis, MO 63119-3194

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Don't miss the ACT Annual Conference on October 19 and 20 in Atlanta, Georgia!

Traditionally described as the Gateway to the South, Atlanta is a bustling city with many attractions. For an introduction to all the city has to offer, visit the Atlanta Convention and Visitors Bureau home page at http://www.acvb.com.

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