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Inside Numbers

Each year more U.S. parents find that their children's mathematics home work is vastly different from what math was when they went to school. This is the "new math," and the change goes back to 1952, when Mathematician Max Beberman and others became alarmed that math teaching in U.S. schools had not changed essentially in 150 years. In pioneering new methods at the University of Illinois, Beberman sparked a movement that has now influenced about 10% of U.S. elementary schools and 60% of high schools. This year Texas assigned 30,000 teachers to learn new math. This month California decided to spend almost $10 million for new math texts.

What is really new about new math is the teaching; it is basically old math taught in a far better new way. The purpose is to replace numb learning of rote computation with a confident understanding of the structure and relation of numbers—the why of the drills. Rules and formulas are still vital tools, but new math aims to go back to the sources of the rules to show why they are valid, rather than blindly prescribing them.

The Wonder of Zero. Math is the study of patterns; numerals symbolize real things—the size of collections, the length of lines, the position of points. New math thus begins on the concrete level and only later moves to the abstract. Math is also a unified system; new math thus shows the interrelation of all branches, such as algebra and geometry, rather than teaching them as separate topics. The stress is on "discovery"—the artful question that sparks a child's desire to see patterns and find answers. The idea is to get children inside the structure of numbers by means of a "spiral curriculum"—constant re-translation of concepts at higher orders of sophistication.

In laying out the floor plan—arithmetic—new math begins not with the names of numbers but with real objects, such as beads, stones, sticks. By manipulating objects in collections (or "sets") the child learns crucial ideas. He may be asked to remove pairs of objects from two collections, for example. When both collections run out at the same time, he begins to grasp the idea of equality. When one runs out first, he learns about inequalities.

Equal collections of different things bring up the idea of number as a common property of the sets; then the child can move on to grasp the symbolism of numbers expressed as numerals. He sees that for convenience the first ten symbols may be recombined for numbers greater than nine. He may also learn that each digit (say in 326) has a "place value" ten times that of its neighbor to the right (three hundreds, two tens, six ones). He discovers the wonder of that great ancient invention, zero, the "place holder" that allows infinite expansions (606 would be simply 66 without it).

5 = 101. All this stems, of course, from the fact that man has ten fingers. With eight fingers, he might have invented a base-eight number system. Many children now explore the base-two (binary) system, used in computers, which depends only on 0 and 1 . They alarm parents with the news, for example, that seven is not 7 but 111, each digit is twice the one to the right: one 4, one 2, one 1, adding up to 7, each digit is twice the one to the right; one 4, one 2, one 1, adding up to 7. Similarly, 5 is 101 (one 4, no 2s, one 1). Once they are well grounded in the new math concepts, even small children can easily "carry" and "borrow" with large numbers. They simply "regroup" by tens:

943 = 900 + 40 + 3

+ 729 = 700 + 20 + 9

1,600 + 60 + 12 = 1,672

883 = 800 + 80 + 3 = 800 + 70 + 13

-657 = 600 + 50 + 7 = 600 + 50 + 7

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200 + 20 + 6 = 226

Visible Laws. The same beads and stones that he starts with also let the child see how numbers behave when he puts several collections together (addition and multiplication), or when he takes them apart (subtraction and division). This reveals all sorts of relations—for example, that 8 + 5 is the same as 5 + 8 (the commutative law); that subtraction (8 -5 = ?) can be expressed as addition (5 + ? = 8); that division is the inverse of multiplication 10/2 = 5 because 5 X 2=10); and that the commutative law also holds for multiplication, as in the array:

5X3 · · ·

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=

3X5 · · · · ·

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Equally clear is that a multiplier can be distributed among the terms it multiplies (the distributive principle). Third-graders learn it with an equation such as (6 X 4) + (3 X 4) = (9 X 4). They can see it with ease:

6 X 4 · · · ·

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. . . .

+

3 X 4 . . . .

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9 X 4 . . . .

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Using such tools as Cuisenaire rods—wooden units of various related lengths and colors—children in early grades carry on these principles to build cubes and squares that introduce them to square numbers. With rods they can easily "see" even such an advanced algebraic factoring problem as x2 - y2 = (x + y) (x -y):

Why 2/3 of 3/4 Is 1/2. New math teachers also make use of the "number line," which shows the sum of same-size jumps from point to point:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

—>l—>l—>l—>l—>l—>l—>l

3 3 3 3 3 3 3

Number lines tell the novice much about fractions. When he takes three of four segments and divides their sum into thirds, he discovers that two of these thirds make one-half of the full unit. He thus has visible proof of the otherwise abstruse fact that 2/3 times 3/4 equals 1/2. By extending the number line leftward beyond zero, he visualizes the concept of negative numbers.

The most ingenious use of an old mathematical toy is the endless variety of "cross number puzzles" in the workbooks of Robert W. Wirtz and Morton Botel, which give the child a couple of number clues (here printed in red) and thus prod him to hot pursuit of sums and products (in black) that illuminate the relationship of addition and multiplication.

Cultural Calculus. All this opens the way to very early algebraic notation, at first using squares and triangles as symbols. A teacher might ask: If the boxes contain the same number, how should ■ + A - ■ = 6 be completed? One first-grader's immediate answer: any number for the boxes, but only 6 for the triangle. In one of his experimental classes, reports Mathematician Robert B. Davis of the Missouri-based Madison Project, one third-grade boy actually invented a new way of subtracting by junking the borrowing process in 64 minus 28. His answer: "Subtracting 8 from 4 gives minus 4. 20 from 60 is 40, and 40 plus a minus 4 equals 36, so the answer is 36."

Such "intuitive preparation," as Max Beberman calls it, is the key to great changes in better schools. Algebra is no longer taught as a collection of rules, with proofs reserved to geometry, for example. The subjects are complementary, and now begin in grade school. Plane and solid geometry are merged, allowing simultaneous treatment of a problem in two and three dimensions. More high schools teach statistics and probability; trigonometry stresses analysis of trigonometric functions rather than archaic solution of triangles.

Adult Sixth-Graders. Most Americans dread math because teachers have long used strong-arm drills to mask their own ignorance of the subject; even now more than half the states do not require a single college math course for certified elementary schoolteachers. Taught rote computation, children have usually lost all curiosity in the process. As an instance, most kids must still wait for third grade to tackle such "carrying" problems as 39 plus 3, even though first-graders can easily do it by counting

40, 41, 42 on their fingers.

Math is not only vital in a day of computers, automation, games theory, quality control and linear programming; it is now also a liberal art, a logic for solving social as well as scientific problems. How much more of it Americans might have is suggested in the new Cambridge Report, a manifesto by 25 top U.S. math users and teachers who hammered it out at Harvard. To lift the national logic level and stamp out mathematical illiteracy, these experts argue that sixth-graders can and should attain a competence "well above that of the general population today." For high school graduates, they prescribe two years of calculus and a knowledge "comparable to three years of top-level college training today."

The main danger in new math is that it may get too rigid as it spreads more widely. Critics also worry about fads, such as "set theory," a broadly unifying pure math concept that children probably cannot handle at a worthwhile level. But no one is talking about going back to old math. U.S. mathematical literacy can no longer be considered, as Robert Davis puts it, "a matter of God and heredity."

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