"... real comprehension implies re/invention. . . ." Jean Piaget

The Educational Need to Re-Invent the Wheel

WILLIAM E. DOLL, JR.

According to one of the most respected educational maxims, the teacher should not make the learner re-invent the wheel. Rather, the teacher's task is to give each student a knowledge base for further exploration and development.

Dewey, however, was famous for his objection to the "giving" of knowledge:

> No thought, no idea, can possibly be conveyed as an idea from one person to another. When it is told, it is, to the one to whom it is told, another fact, not an idea. . . . What he (the person) directly gets cannot be an idea. Only by wrestling with the conditions of the problem at first hand, seeking and finding his own way out, does he think (1966, pp. 159-160).

Thinking is different from learning. In learning, one can copy, follow someone else's formula or paradigm, maybe even extend it a bit; but the more the pattern is extended into new areas, the more there is need for a new and different act—that of thought. Dewey identified thinking with active reconstruction. Piaget (1974) agreed that "for a child to understand something, he must re-invent it."

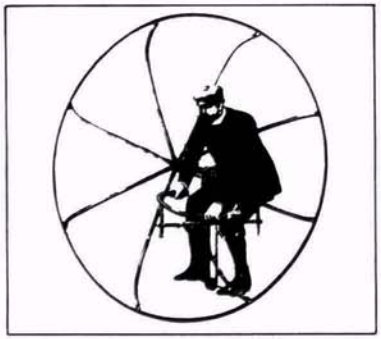
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A Structural Curriculum for Math

For the past three years we at the State University of New York at Oswego have been working on a structural arithmetic curriculum designed to help students re-invent the wheel or, more precisely, develop their own powers of thought.

The task of devising a curriculum to foster thinking has been formidable. When we say re-invent we do *not mean* that the learner will (1) do whatever he or she wishes, or (2) re-invent all wheels. Rather, the overall thrust will combine giving and doing (both active and reflective doing) so that the intellectual powers of the learner will be of primary concern. We have tried to integrate the structures of the field, arithmetic, with the structures of the learners, primary grade children. Our guiding maxim has been:

> The task of teaching a subject to a child at any particular age is one of representing the structure of that subject in terms of the child's way of viewing things (Bruner, 1973, p. 413).



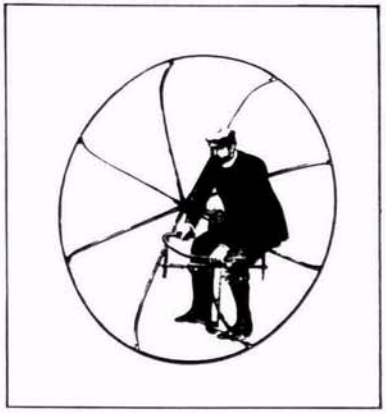
As a general guide this is fine, but as an operational reality it leaves much to be worked out. The structures of arithmetic—such things as reversibility, identity, equality—are the very logical structures primary grade children do not yet possess. The basic intellectual structures of arithmetic, such as place value, are just not formed in the average primary grade child. Thus it was only at the end of the school year that our third graders began to understand place value in a way that allowed them to work the system in a creative and inventive manner. Yet the usual school curriculum expects place value to be taught in the second grade.

On the other hand, once children have acquired structural learning—learning that Bruner would say is generic or abstract, having within it Piaget's "real comprehension"—they can transfer and transform knowledge almost at will. An example would be the ease with which our third graders moved from two-digit place value to two-position

combinations, from 56 or 65 to AB or BA; from three-digit place value to six-position combinations and permutations; from 123, 132 to ABC, ACB, BAC, BCA, CAB, CBA. They then moved to four-item permutations (24 possible combinations) and five-item permutations (120 possible combinations). A few even saw the pattern that produced these logical possibilities. This sort of transfer and transformation is natural, though, because the basic structure underlying place value and combinations-permutations is the same. The art of teaching this sort of transfer and transformation requires a knowledge of both the field's structure and the learner's structure, as well as a sense of timing. In the individual's own re-invention, he or she is able to take the qualitative leaps it took humankind hundreds of thousands of years to make.

The day-in and day-out practicality of the structural arithmetic curriculum is based on seeing relationships among numbers and organizing those relationships into systems. In the first and second grades there is strong emphasis on what teachers normally call "number families" (3+5, 5+3, 8−5, 8−3, and so on). This relational concept is also applied to multiplication-division, to addition-multiplication, and to odd-even. In the third grade, relationships are expanded to help the student do multiplication via the process of doubling or halving (8 x 7 can be done as 2(4 x 7) or 28 + 28, as 16 x 7 can be done as 56 + 56). This doubling-halving process is then combined to produce work with the identity element for multiplication. Our third-grade children are comfortable and skillful with doing 12 x 15 as 6 x 30 (halving one number, doubling the other). Most of the present experimental group can mentally perform two-digit multiplication or division by one digit, and a few are able to do two-digit by two-digit multiplication. That is, 36 x 12 can be done mentally as 12 x 12 x 3 or 144 x 3, or even as 288 + 144.

It is exciting to watch third grade children (our most advanced group so far) do complex equations, but it is far more exciting to watch the enthusiastic openness and skillful dexterity they possess as they tackle new and different situations. The curriculum project is now in its fourth year. Our most advanced group has remained together for three years as an experimental group, counterbalanced by a three-year control group. While all statistical results are not yet in, the experimental group has been performing significantly better than the control group on national achievement and cognitive abilities tests given each fall and spring.



However, to test competence, the basic abilities underlying performance, we have gone to multiple-case studies. Here we have questioned the third grade children individually and in-depth on the procedures they've used in doing problem or exercise assignments. We have used a broad range of individual interviews on work material drawn from both the experimental and control groups. Clear, procedural differences have emerged. As one experimenter remarked, "The knowledge the children in the experimental group have is their own knowledge, while those in the control group are always trying to follow the teacher."

For the experimental group, re-invention has paid off in terms of confidence, innovation, and intellectual sophistication. These children are quite willing to tackle most any problem or exercise and to figure out a solution. The control group is much more constrained. Almost regardless of ability, they are fearful and inept at venturing beyond the bounds of what they have been taught. If the material is new, they will venture such remarks as: "I've not been taught that"; "We can't do that"; "I don't know how." In short, one group has been trained in a narrow view of learning where learning is equated with copying, while the other group has been trained in a broader, more inventive framework where learning is the springboard to thinking.

"Curricular failings are not the result of teacher incompetence. . . ."

Re-Inventing Our Models

A judicious mixing of the given and the discovered, with an emphasis on structure, enables students to perform more efficiently than those trained in the normal modes of curriculum. Curricular failings are not the result of teacher incompetence; the teachers usually teach as well if not better than we teach them to teach. Rather, the basic failings are deeply ingrained in society. We have adopted a scientific model well suited to the production of technological objects, but it has not been well suited to the development of human thought processes.

We need to pay more attention than we have to Dewey's distinction between the scientist and the teacher. The scientist needs to know the field; the teacher needs to know both the field and the learner. The teacher must know how to help the learner know that field in such a way that the learner can operate without the aid of the teacher. The educational model most schools have been using is not designed to accomplish this task. ■

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