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ABSTRACT

In this brief review, research on varying types of instructional materials is summarized. The evidence indicates that the textbook is the most widely used instructional material, and few teachers appear to use any other materials more than five times a year. Research findings on the value of the use of manipulative materials seems clear: they have a high probability of increasing achievement, and appear to be essential in providing a firm foundation for developing mathematical ideas. While textbooks and tests shape the curriculum, studies indicate that the match of topics between the two cannot be taken for granted. While most children at all grade levels have access to or own calculators, few teachers actually use them in the mathematics classroom. Nevertheless, achievement scores are as high or higher when calculators are used for mathematics instruction as when they are not used. The usefulness of computers is accepted, but the task of integrating them into the curriculum has just started. Each of the findings is discussed, with illustrative references cited. (MNS)

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Research on Instructional Materials for Mathematics

"Instructional materials" conjures up the image of a vast array of materials, devices, and other articles to aid in teaching mathematics: blocks, the abacus, Cuisenaire rods, chip trading games, spinners, as well as calculators and computers. Reality, however, is apparently something else. Textbooks and tests predominate.

Amount of Use

Research evidence, garnered from observing teachers and classrooms and from asking teachers, indicates that most teachers use one instructional material: the textbook (e.g., Weiss, 1978). In a survey by Scott (1983), few teachers in one district reported using **any** other materials more than five times a year.

Furthermore, the use of non-textbook materials peaks in grade 1, and the percentage decreases as grade level increases. By the intermediate grades, few teachers use other materials, and by grade 7 the percentage is practically zero.

And yet teachers respond to questionnaires in ways that indicate that they believe that the use of manipulative materials is important!

Manipulative Materials

The evidence on the value of the use of manipulative materials is very clear: they have a high probability of increasing achievement, and appear to be essential in providing a firm foundation for developing mathematical ideas. Suydam and Higgins (1977) reported from an analysis of a large number of studies that lessons using manipulative materials have a higher probability of producing greater mathematical achievement than do lessons in which such materials are not used. This appears to be true across a variety of mathematics topics, at every grade level, at every achievement level, at every ability level. Later research (e.g., Canny, 1984) continues to provide support for this finding. Stanley (1984) stated that "mathematics materials and practices played a significant role in the improved student achievement that occurred" in his comparison of more effective and less effective schools. In scores of other articles, the need to develop mathematical ideas with materials is underlined.

It appears possible that having children manipulate materials themselves may not be necessary for some topics. Watching the teacher use materials in a demonstration mode was sometimes at least as effective. It may be that at times it is easier to direct children's attention to important points when the teacher is in control of the materials.

Many of the studies provide at least partial support for the use of materials in stages progressing from concrete to pictorial to abstract or symbolic. The use of either or both physical and pictorial aids results in significantly higher achievement than when only symbols are used. The developmental level of the learner needs to be considered, but there is evidence that students can profit from the use of materials for many topics right through senior high school. The material needs to fit the mathematical idea — and the learner's needs.

Varying levels of cognitive development exist in any classroom. Most elementary school pupils, and many secondary school students, deal well only with symbols that are closely tied to their perceptions. Thus, they need to see concretely that 2/3 of 2/3 is 4/9, not just move numerals. Moreover, a major reason for patterns of errors in using paper-and-pencil procedures is that manipulative materials are abandoned too early when they are used. Spatial-visual perceptions strongly influence children's mathematical conceptualizations, and learning requires **active** participation by the learner.

Manipulative materials must be used at the right time and in the right way if they are to be effective (e.g., see Clay, 1985). Materials must be selected with the mathematical purpose clearly in mind. Children's attention must be focused on the objective, and they must be encouraged to "think along" as they use materials. The steps in the progression from use of materials to use of symbols must be linked, with meaning developed through bridging from concrete to abstract. Thus, manipulatives are used to "mirror" or model what is done with symbols, and discussion on how manipulatives relate to symbols must be encouraged. As Campbell indicated, "Young children have differing interpretations of pictures and may not perceive the mathematical relationships which are depicted. The transfer from concrete objects to pictures and from pictures to numerals must be taught; it cannot be assumed" (1984:16).

Textbooks and Tests

There is little doubt that textbooks and tests shape the curriculum. Freeman et al. (1983) analyzed the extent to which the same topics are emphasized in four textbooks and five standardized tests for grade 4. All materials dealt with computation and geometry, but there the similarities ended. Of 385 topics identified in the materials, only 9 were common to all tests, while 19 were represented in all four textbooks. (It is important to note, however, that this set of common topics received a great deal of attention — approximately 50% to 60% of the textbooks.) Only six topics were emphasized in all four textbooks and on all five tests.

As the researchers note, "Many factors implicit in the design of standardized tests make it unreasonable to expect a one-to-one correspondence between content covered in textbooks and tests" (p. 508). Tests include only a sample of the content. However, the topics tested were not always those most emphasized in textbooks! Overall, the results "suggest that diversity rather than consensus is likely to characterize the mathematics curricula" (p. 511). Furthermore, "When there are mismatches between content taught and content tested, standardized tests underestimate student achievement" (p. 511). Thus, "any comparison or simple interpretation of student performance on standardized achievement tests must consider the match between content taught and content tested" (p. 512).

These findings are supported by other studies; for instance, Rogers (1981) compared one state's minimum competency objectives and performance indicators to the content of two textbook series for grade 3-8. Twelve performance indicators received no textbook instruction, and many indicators received little practice.

Surprisingly, there is little evidence on how textbooks are used. Brown (1974), however, provided evidence from in-

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terviews, observations, and questionnaires of teachers of geometry and second-year algebra. They used special features of the textbook infrequently. The textbook was nevertheless followed very closely, and teachers rarely presented topics not in the textbook. The major objective tended to be to complete the exercises at the end of each section. Thus mathematics, Brown states, "was resolved into a sterile sequence of homework-discussion-new homework."

How students learn from textbooks has also rarely been explored. Neves (1982) used a computer program to analyze examples in an algebra textbook, developing conjectures and demonstrating how it is possible to go from novice to expert behavior through experience with examples; how examples with skipped steps can be learned from; how it is possible to learn from examples embedded in other examples; and so on. This type of computer technique may prove helpful in the **development**, as well as the analysis, of curricular materials.

Calculators

National assessment data indicate that most children at all grade levels have access to, or own, calculators. While many teachers indicate that they believe that calculators should be used in schools, far fewer actually use them (Reys et al., 1980). Moreover, the arguments that have persisted since the mid-1970s, when calculators first became viable for use in schools as prices dropped, are still with us. Many people are still afraid that calculator use will mean loss of paper-and-pencil computation skills (however little those are actually used in real life).

Over 150 studies on the effects of calculator use were reviewed by Suydam (1982). About half of these studies had one goal; to ascertain whether using calculators would harm students' mathematical achievement. In all but a few **instances, achievement scores were as high or higher when calculators were used for mathematics instruction as when they were not used.** Hembree (1985), reviewing 79 studies, confirmed that (except at one grade level) use of calculators improved students' basic skills with paper and pencil. Moreover, better attitudes toward mathematics and an especially better self-concept in mathematics were found.

It has also been found that calculators are particularly helpful in teaching many mathematical ideas. Problem-solving achievement, for instance, is enhanced, and different strategies and solution methods are used. The calculator makes the exploration of hypotheses feasible, and is useful in developing counting, computation, estimation, and other matematical skills.

Computers

Computers have been used in schools since the 1960s, but of course attention today is focused on the use of microcomputers. Surveys indicate that microcomputers are found in well over half of our schools, and their use in mathematics classes accounts for a large proportion of their use. However, the concern has shifted to **how** they are being used, with the National Council of Teachers of Mathematics — and most mathematics educators — taking the position that no longer should the mathematics teacher be largely concerned with teaching computer programming and computer literacy. We know from research that computers can be used effectively for problem solving, drill and practice, tutorial instruction (CAI), management, games, programming, and simulations. The focus for mathematics teachers is now on ways to incorporate computer applications more meaningfully into mathematics instruction.

The impact on the curriculum and on insruction of technological tools has yet to be feit. Moveover, concern has increased about the role of textbooks and tests. Together they have formed a chicken-egg analogy for the curriculum: textbooks "cannot" change until tests do, and tests "cannot" change until textbooks do. How to break this cycle so that the mathematics curriculum can keep pace with changing societal needs, is the concern of several groups, most notably the National Council of Teachers of Mathematics and the Association for Supervision and Curriculum Development.

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