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Experiential Learning of Mathematics: Using Manipulatives. ERIC Digest.

Experiential education is based on the idea that active involvement enhances students' learning. Applying this idea to mathematics is difficult, in part, because mathematics is so "abstract." One practical route for bringing experience to bear on students' mathematical understanding, however, is the use of manipulatives. Teachers in the primary grades have generally accepted the importance of manipulatives. Moreover, recent studies of students' learning of mathematical concepts and processes have created new interest in the use of manipulatives across all grades.

In this Digest "manipulatives" will be understood to refer to objects that can be touched and moved by students to introduce or reinforce a mathematical concept. The following discussion examines recent research about the use of manipulatives. It also speculates on some of the challenges that will affect their use in the future.

DEVELOPMENT OF MANIPULATIVES FOR TEACHING MATHEMATICS

Both Pestalozzi, in the 19th century, and Montessori, in the early 20th century, advocated the active involvement of children in the learning process. In every decade since 1940, the National Council of Teachers of Mathematics (NCTM) has encouraged the use of manipulatives at all grade levels. Every recent issue of the "Arithmetic Teacher" has described uses of manipulatives. In fact, the entire February 1986 issue considered answers to the practical questions of why, when, what, how, and with whom manipulative materials should be used.

Research suggests that manipulatives are particularly useful in helping children move from the concrete to the abstract level. Teachers, however, must choose activities and manipulatives carefully to support the introduction of abstract symbols. Heddens divided the transitional iconic level (the level between concrete and abstract) further into the semiconcrete and semiabstract levels, in the following way:

The semiconcrete level is a representation of a real situation; pictures of the real items are used rather than the items themselves. The semiabstract level involves a symbolic representation of concrete items, but the pictures do not look like the objects for which they stand. (Heddens, 1986, p.14)

Howden (1986) places specific manipulatives on this continuum. These manipulatives rank from the concrete to the abstract. In place value, for example (going from concrete to abstract), they include pebbles, bundled straws, base-ten blocks, chip-trading, and the abacus. Howden cautions that building the bridge between the concrete and abstract levels requires careful attention. She notes that, even if children can solve a given problem at the concrete level, they may not be able to solve the same problem at the abstract level. This problem occurs if the bridge has not been structured by a careful choice of manipulatives.

Suydam and Higgins (1977), in a review of activity-based mathematics learning in grades K-8, determined that mathematics achievement increased when manipulatives were used. Sowell (1989) performed a meta-analysis of 60 studies to examine the effectiveness of various types of manipulatives with kindergarten through postsecondary students. Although these studies indicate that manipulatives can be effective, they suggest that manipulatives have not been used by many teachers.

IMPLEMENTATION OF MANIPULATIVES IN GRADES K-12

The reasons that teachers do not use manipulatives are beyond the scope of this Digest. Several related issues are, however, relevant within the scope of this Digest. Sowell (1989) found that long-term use of manipulatives was more effective than short-term use. Even so, when manipulatives are used over an extended period of time, teachers' training critically influences effectiveness. Gilbert and Bush (1988) examined the recognition, availability, and use of 11 manipulatives among primary teachers in 11 states. Results indicated that inexperienced teachers tended to use manipulatives more often than experienced teachers. (A possible explanation is that experienced teachers lack the training that more recent graduates have had.) Directed-inservice training with manipulatives, however, increases use among all teachers.

Availability is probably the most important factor affecting the use of manipulatives. Certainly, if manipulatives are unavailable, teachers cannot use them. Nonetheless, many manipulative materials--such as buttons and spools--can simply be collected by teachers. Others, such as beansticks and attribute blocks, are easy to make.

Consideration of these factors has led to the appropriate use of manipulatives at specific grade levels. The Middle Grades Mathematics Project (Lappan, Fitzgerald, Phillips, Shroyer, & Winter, 1986), for example, is an activity-based mathematics program in which such manipulatives as tiles, cubes, geoboards, dice, and counters are used. Here the students continually explore by building, drawing, and discussing various "challenge situations."

Manipulatives have, unfortunately, been implemented more slowly at the secondary level. As a result, research on their effectiveness at this level is minimal. One example, however, is Howden's (1986) application of tiles to help ease the transition to the abstract level in algebra. The tiles model the basic concepts of polynomials, from definitions to multiplying and factoring polynomials. The program's focus on connecting geometry to algebra allows students to apply previous knowledge to new topics. As they use the tiles, students are continually encouraged to draw pictures and to see mental images.

The closest thing to an integrated K-12 activity-based mathematics program based on manipulatives has been developed by Mortensen. This five-year-old program, Mortensen More Than Math (1988, Hayden Lake, Idaho), uses manipulatives and workbooks to teach five strands: algebra, arithmetic, calculus, problem-solving, and measurement (including both geometry and trigonometry). Some school systems and states have approved all or parts of the program, but formal research on its effects is not yet available.

NEW DIRECTIONS FOR PUTTING THEORY INTO PRACTICE

Two influences will probably affect the use of manipulatives in the future. These influences are: (1) schools' efforts to conform to the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989); and (2) the commitment of state resources to transform theory into practice.

The Standards will doubtless be a major influence. They: (1) describe competencies in broad areas, such as geometry, algebra, statistics, and probability; and (2) specify instructional strategies for grades K-4, 5-8, and 9-12. The Standards include a new approach for evaluating specified competencies. The new approach involves greater use of open-ended questions, descriptions of problem-solving processes, and drawings to represent geometric situations. To help students attain the competencies, the Standards (pp. 17, 67-68) explicitly recommend a sample list of manipulatives for each classroom in grades K-8. No specific list of manipulatives is recommended for grades 9-12, unfortunately. Many students at this level will, however, need to have ideas introduced at the concrete level.

STATE INITIATIVES

Some state and local systems have mandated the implementation of manipulatives through policy, law, or curriculum documents. Some have also provided various levels of funding. One of the strongest philosophical positions has been taken in California. In that state, the use of manipulative devices in all elementary classrooms is recommended (Gilbert & Bush, 1988). The state framework, approved in 1985, emphasizes student use, rather than teacher-directed demonstrations. California, interestingly enough, examined 14 textbook series and compared them to the framework, for possible adoption. All were turned down. One of the major reasons cited for this action was the lack of concrete materials to introduce concepts and to provide reinforcement until understanding occurs.

North Carolina has made a significant commitment to the use of manipulatives in its schools. Manipulative kits for primary (K-3), intermediate (3-6), and secondary (7-12) levels have been designed. State funding has provided for at least one kit in each elementary school (Center for Research in Mathematics and Science Education, 1988). Yet, in a survey of 964 elementary teachers in North Carolina, only 11.2 percent reported frequent use of the kits. Moreover, 9.5 percent were apparently unaware that the kits were even available.

Tennessee's mathematics curriculum guides for grades K-8 state that new concepts will be introduced through concrete experiences. To facilitate this goal, the guides' objectives have been written in concrete, iconic, and abstract terms. The secondary guides encourage, rather than mandate, the use of manipulatives. The Mathematics Activity Manuals (Center of Excellence for the Enrichment of Science and Mathematics Education, 1989) for grades K-8, Algebra I and II, Unified Geometry, and for Selected Topics From Advanced Mathematics Courses have been developed for use with the guides. They are being field tested during 1989-1990. The activities for objectives at all three levels include patterns for inexpensive non-commercial manipulatives. Tennessee has provided no funding for manipulatives.

Chapter 75 of current Texas law states that new concepts should be introduced with appropriate manipulatives at the elementary and secondary levels (Peavler, DeValcourt, Montalto, & Hopkins, 1987). Students are to be actively involved in structured activities that develop understanding and the ability to apply skills. Evaluation of mastery at the concrete level is supposed to include student demonstrations with manipulative materials. Minimum manipulative kits are described and are to be made available in each classroom, at each grade level K-8. Local districts, however, must provide funding.

AREAS FOR INCREASED ATTENTION

As the decade of the 1990s dawns, research on the effectiveness of manipulatives in grades K-8 will doubtless continue. Forthcoming research should also seek to study the use and effects of manipulatives at the secondary level. Increasing the use of this experiential strategy at both levels will require more states to make the type of financial commitment that those in the forefront have already made. In that vein, studies should be carefully designed to determine the impact of different funding formulas for effectively implementing this teaching strategy across the grades.

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