Mathematics Laboratories: What Does Research Say?

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EDUCATION has, for years, been confronted with "new" curricula, "new" programs, "new" techniques. Much of the "newness" in education is a rejuvenation of past ideas. For example, Bernard (1972) in his dissertation, "The Historical Development of the Laboratory Approach to Elementary School Mathematics," traced the concept of mathematics labs to 1895 when A. R. Hornbrook wrote her book, *Laboratory Methods of Teaching Mathematics in Secondary Schools*. Since that time, mathematics labs have received periodic attention as a teaching technique. The current emphasis on mathematics labs is partially related to the trend in educational philosophy and psychology which promotes active rather than passive learning, involvement in learning, critical thinking, inquiry, and relevancy. Mathematics labs have also received the support of leading educators, for example, Dienes, Kidd, Spitzer, and Biggs.

Much attention has been focused on the mathematics lab as an approach to teaching; an example of this was a symposium, "Cognitive Psychology and the Mathematics Laboratory," held at Northwestern University in February 1973. The purpose of this article, therefore, is to review the research which has been done in relationship to the mathematics laboratory as a teaching technique.

The use of manipulative aids is often assumed to be an integral part of the mathematics laboratory. A broad study which attempted to establish the availability, purpose, and use of manipulative aids in the elementary school mathematics program was conducted by Green (1970). He reported that manipulative materials were used more for demonstration in the sixth grade, while in other grades they were used more for manipulation by the students.

Other studies attempted to determine the effectiveness of using manipulative materials in preschool and primary mathematics instruction. Jones (1971) reported that matching skills but not copying skills improved with four- to six-year-old disadvantaged children who had plastic numerals available for free play use.

In working with first grade students, Weber (1970) found there was no significant difference between reinforcement of concepts with manipulative materials or with paper-pencil activities. However, she did report that a trend favored the use of materials,

especially for children of low socioeconomic status.

Studies involving second grade students indicated results which were not consistent with achievement in mathematics. Fennema (1970) compared the effects of a meaningful concrete and meaningful symbolic model in facilitating learning of a selected mathematical principle. She established there were no significant differences in overall learning of the principle. However, she did report that the symbolic model resulted in significantly better transfer of learning.

Kamps (1971) experimented with different methods useful in helping second graders acquire skills in conservation and measurement of length. No significant differences were found among groups of children having AAAS, Cuisenaire, or "limited experiences." Interestingly, fewer than one-third of the pupils achieved any of the conservation or measurement tasks.

Knaupp (1971) investigated the use of manipulative models (blocks and sticks) and modes of instruction (teacher-demonstration and student-activity) in the numeration system. He determined that both the manipulative models and the teaching modes resulted in significant gains in achievement, but that no significant changes occurred in attitude with the second graders.

A few studies investigated the effect of concrete materials on the arithmetic achievement of intermediate students. Carmody (1971) found that sixth graders using semi-concrete materials scored significantly higher than the symbolic group on a numeration test.

However, no significant differences were found between groups using concrete or semi-concrete materials. All groups using materials scored higher on tests of transfer than those groups not using materials. Curry's (1971) research findings were in agreement with those of Carmody. Curry's work with eight- through ten-year-old children indicated that instruction involving concrete materials or pictures resulted in greater arithmetic achievement than did the verbal methods.

In two studies, fifth grade students' achievement in working with fractions was found to be significantly greater when manipulative materials were used. Bisio (1971) reported that passive use of manipulative materials was apparently as effective as active use and better than non-use when working with fractions. Bohan (1971) established that groups using diagrams or paper-folding scored significantly higher on a test on equivalent fractions than those using the "property of one" procedure. The paper-folding group scored significantly higher on a retention test and on a test measuring attitude.

Johnson (1971) tested the effects of concrete activities when teaching geometric concepts of perimeter, area, and volume to groups of fourth to sixth grade students. He reported higher mean achievement and reten-

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tion scores when activities were highly concrete.

The effectiveness of manipulative materials is not limited to young children. Anderson (1957), Johnson (1971), and Myrick (1970) have each reported studies using various manipulatives to teach selected concepts to middle school age children. All reported that concrete manipulative materials improved achievement. Retention was a dependent variable in the studies by Johnson (1971) and Anderson (1957); and in both studies, retention was greater in the experimental groups.

During the period reviewed, several research studies were found to be explicitly concerned with the idea of mathematics laboratories. Wilkinson (1971) found that there were no significant differences in achievement produced by the use of the laboratory method to teach geometry to sixth graders. Conflicting results were obtained by Cohen (1971) and by Vance and Kieren (1972) concerning the effectiveness of the laboratory method with seventh and eighth graders. Kieren found that the mathematics laboratory produced significantly higher achievement results and that children reacted positively to the experimental method. Cohen (1971) reported that few changes in attitude were noticed and that the control group outperformed the mathematics laboratory group.

The laboratory method served as an independent variable in a study by Browman (1938) to measure the outcomes of two methods of teaching geometry to ninth and tenth graders. The results showed that the laboratory method was superior or equal to the lecture-demonstration in all areas tested.

Research efforts during the preservice training of elementary teachers have produced consistent findings. Both Postman (1971) and Boonstra (1970) reported that involvement in laboratory experiences during preservice training does not affect the teaching behavior of the subjects.

In summary, manipulative materials and mathematics laboratories seemed to be used interchangeably in the secondary levels, while the elementary school hardly ever is associated with the term "mathematics laboratory." It seems that there is a need to develop a definition of mathematics laboratory for both elementary and secondary levels so that related research may be more meaningful.

The studies reviewed showed that mathematics laboratories were used more for developmental, as opposed to drill and practice, activities. The results of a majority of the studies indicated that the mathematics laboratory was superior to other methods in increasing achievement, retention, and transfer.

Finally, the manipulatives used in the studies were not often explicitly described. Research efforts showing the effectiveness of particular aids in a laboratory setting should be readily available to classroom teachers.

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