DOCUMENT RESUME

ED 332 862 SE 050 919

AUTHOR	Leighton, Mary S.; And Others
TITLE	Achievement Effects of Individual, Small Group, and Cooperative Learning Strategies on Math Problem-Solving. Report No. 40.
INSTITUTION	Center for Research on Elementary and Middle Schools, Baltimore, MD.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	May 89
CONTRACT	OERI-G-90006
NOTE	17p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Cooperative Learning; *Grade 7; *Grouping (Instructional Purposes); *Heuristics; Individualized Instruction; Junior High Schools; Mathematical Applications; *Mathematics Instruction; Mathematics Skills; *Problem Solving; Small Group Instruction

ABSTRACT

This study examined the use of heuristic problem-solving strategies in math by seventh-graders under three different conditions: working individually; working in groups; and working as cooperative teams. No significant differences were found for the three conditions over a 5-week experimental period on a problem solving post-text (the Maryland Functional Math Test), but students in all three conditions did significantly outperform a control group which did not receive instruction in using heuristic practices and which did not concentrate as much on problem-solving. Thus the study implies that student use of heuristic problem-solving strategies in itself may be effective in various instructional contexts. Twenty references are listed. (Author)

Center for Research On Elementary & Middle Schools

Report No. 40

May, 1989

ACHIEVEMENT EFFECTS OF INDIVIDUAL, SMALL GROUP, AND COOPERATIVE LEARNING STRATEGIES ON MATH PROBLEM-SOLVING

Mary S. Leighton, Robert E. Slavin, The Johns Hopkins University
Neil Davidson, University of Maryland, College Park

Center Staff

Edward L. McDill, Co-Director
James M. McPartland, Co-Director

Karl L. Alexander
Henry J. Becker
Jomills H. Braddock II
Renee B. Castaneda
Barbara S. Colton
Diane B. Diggs
Doris R. Entwisle
Joyce L. Epstein
Anna Marie Farnish
Denise C. Gottfredson
Gary D. Gottfredson
Edward J. Harsch
Brigette B. Hinte
John H. Hollifield
Lois G. Hybl
Marva J. Jeffery
Nancy L. Karweit
Melvin L. Kohn
Mary S. Leighton
Barbara M. Luebbe
Nancy A. Madden
Barbara E. McHugh
Laura B. Rice
Karen C. Salinas
Dorothy C. Sauer
Robert J. Stevens
Shi-Chang Wu

Center Liaison

Rene Gonzalez, Office of Educational Research and Improvement

National Advisory Board

Patricia A. Bauch, Catholic University of America
Jere Brophy, Michigan State University
Jeanne S. Chall, Harvard University
James S. Coleman, University of Chicago
Edgar G. Epps, University of Chicago
Barbara Heyns, New York University
Michael W. Kirst, Chair, Stanford University
Rebecca McAndrew, West Baltimore Middle School
Jeffrey Schneider, National Education Association

Achievement Effects of Individual, Small Group, and Cooperative Learning Strategies on Math Problem-Solving

Grant No. OERI-G-90006

Mary S. Leighton
Robert E. Slavin
The Johns Hopkins University

Neil Davidson
University of Maryland, College Park

Report No. 40

May 1989

Published by the Center for Research on Elementary and Middle Schools, supported as a national research and development center by funds from the Office of Educational Research and Improvement, U.S. Department of Education. The opinions expressed in this publication do not necessarily reflect the position or policy of the OERI, and no official endorsement should be inferred.

Center for Research on Elementary and Middle Schools
The Johns Hopkins University
3505 North Charles Street
Baltimore, Maryland 21218

Printed and assembled by:
VSP Industries
2440 West Belvedere Avenue
Baltimore, Maryland 21215

The Center

The mission of the Center for Research on Elementary and Middle Schools is to produce useful knowledge about how elementary and middle schools can foster growth in students' learning and development, to develop and evaluate practical methods for improving the effectiveness of elementary and middle schools based on existing and new research findings, and to develop and evaluate specific strategies to help schools implement effective research-based school and classroom practices.

The Center conducts its research in three program areas: (1) Elementary Schools; (2) Middle Schools, and (3) School Improvement.

The Elementary School Program

This program works from a strong existing research base to develop, evaluate, and disseminate effective elementary school and classroom practices; synthesizes current knowledge; and analyzes survey and descriptive data to expand the knowledge base in effective elementary education.

The Middle School Program

This program's research links current knowledge about early adolescence as a stage of human development to school organization and classroom policies and practices for effective middle schools. The major task is to establish a research base to identify specific problem areas and promising practices in middle schools that will contribute to effective policy decisions and the development of effective school and classroom practices.

School Improvement Program

This program focuses on improving the organizational performance of schools in adopting and adapting innovations and developing school capacity for change.

This report, prepared by the External Faculty Project of the Elementary School Program, presents the results of a comparison of the use of heuristic problem-solving strategies in math under individual, group, and cooperative learning conditions.

Abstract

This study examined the use of heuristic problem-solving strategies in math by seventh-graders under three different conditions: working individually, working in groups, and working as cooperative teams. No significant differences were found for the three conditions over a five-week experimental period on a problem-solving post-test, but students in all three conditions did significantly outperform a control group which did not receive instruction in using heuristic practices and which did not concentrate as much on problem solving. Thus the study implies that student use of heuristic problem-solving strategies in itself may be effective in various instructional contexts.

Introduction

In recent years, mathematics educators have increasingly focused their attention on math problem solving, defined here as the set of actions taken to perform tasks for which there is no readily available algorithm (Lester, 1980). Findings of the National Assessment of Educational Progress indicate that students are less able to solve complex, non-routine problems than to solve those presented as simple computations.

Research on problem-solving has identified heuristic strategies that good problem-solvers use (e.g., Silver, 1985; Polya, 1957, 1965). Several innovative problem-solving curricula present generic strategies such as "construct a table or picture," "guess and check," "organize facts," and "find a pattern" (e.g., Dolan and Williamson, 1983; Szetela, 1982). These strategies are derived from studies based on the work of Polya (1957), who proposed a four-step process for problem solving: understanding the problem, devising a plan to solve it, carrying out the plan, and "looking back," that is, reviewing the whole process to determine whether the answer makes sense, relative to the original question. However, few evaluations of these strategy training approaches have been made, and little consensus has been developed on how to teach them. Studies have more often examined characteristics of the learners, tasks, overt and covert processes than pedagogical methods.

Both thoughtful analysis of the social aspects of learning and research on strategies effective in other subjects and in other aspects of mathematics suggest that working in small groups ought to operate powerfully in developing math problem-solving skill. For example, Noddings et al. (1983) presented a theoretical rationale based primarily on Vygotsky's work (1978). In discussing problems with peers, students are likely to "examine their own beliefs and strategies more closely and to discard those that are clearly untenable" (p. 13). Further, groups are able to supply their members with missing background information and help one another engage in cognitive elaboration (Silver, 1985). Explaining concepts to others has been known to enhance the understanding of the concepts by the explainer (Webb, 1985).

However, as compelling as the rationale appears, research on this instructional format has not been conclusive, at least in elementary and secondary schools (Davidson, 1985). For the most part, students who solve problems in small groups perform at about the same level on individual assessments of problem-solving ability as do students who studied the same material individually (e.g., Johnson and Waxman, 1985).

Review of previous research reveals three factors indicating that further study of the effects of working in small groups on competence in math problem solving is warranted. First, cooperative learning -- a strategy based on working in small groups -- has been demonstrated to be consistently more effective than traditional instruction in stimulating achievement in math computation (Slavin, Leavey, and Madden, 1984; Slavin, Madden, and Leavey, 1984; Slavin and Karweit, 1984). Second, the achievement effects of the forms of cooperative learning found to be successful in mathematics have been traced to the influence of two elements: group goals and individual accountability (Slavin, 1983a, b).

In successful group strategies, students received recognition or other rewards based on the individual learning of every member of the group. This is in contrast to the procedures used in less successful strategies in which groups worked together to solve a single group problem and may or may not have received rewards or recognition as a group (e.g., Peterson, Janicki, and Swing, 1981; Peterson and Janicki, 1979; Robertson, 1982). These procedures were also characteristic of many earlier studies of cooperative learning which did not employ group rewards in support of problem-solving performance (Davidson, 1985). Third, most of the cooperative learning studies have focused more on instruction in computation than on problem-solving.

In the study reported here, use of cooperative learning with group goals and individual accountability in lessons focused on math problem-solving was investigated. The purpose of the study was to determine whether combining an approach to problem-solving based on heuristic strategies with any of three instructional methods would generate improved achievement and whether any particular combination would produce significantly different results.

Method

Subjects. The subjects in this study were 578 seventh-grade students in 19 classes taught by 8 teachers in one northern Maryland school district. Five middle schools were involved, drawing from a small city and three small towns in farming communities. Almost all students were white and were academically labelled "on-grade" or "enriched" -- i.e., of average ability, neither remedial nor advanced. The teachers volunteered to participate and agreed to have classes randomly assigned to treatments.

Treatments. Three instructional models were used. In all three, lessons began with warm-up drills, based on the skills tested in the Maryland Functional Math Test. This was followed by systematic presentation of the heuristic strategy being taught. In Treatment A, direct instruction, presentation was followed by individual student practice of problems like those in the presentation, followed by individual testing. In Treatment B, team practice, presentation was followed by practice in small, mixed-ability groups, followed by individual testing. In Treatment C, student team learning (STL), presentation was followed by practice in small, mixed-ability teams, followed by individual testing and recognition of *team* achievement gains. Students in the team practice and STL treatments were given instruction in group process skills and support for using those skills. Only in the STL treatment did students earn recognition for average team improvement, rather than for individual success.

Seventeen intact classes, taught by seven teachers, were randomly assigned to the three treatments. Six of the teachers had more than one participating class; random assignment stratified by teacher resulted in all six using two or more different treatments.

Classes used the same curriculum materials, adapted by the teachers from the work of Szetela (1982), and the same warm-up drills and homework assignments.

The curriculum emphasized teaching problem-solving heuristics, such as making a table, guessing and checking, and finding a pattern. All experimental classes participated for 20 teaching days, over a period of about five weeks in April and May, 1988. Two additional classes taught by another teacher constituted the control group, which used the regular district math text (in which problem-solving strategies were integrated into each chapter).

Preparation for the study involved several stages. In early March, teachers were released to participate in a day of training. They reviewed the proposed curriculum materials and the three instructional methods. Their classes were assigned to various treatments. In mid-March, about two weeks before beginning work on the heuristics unit, teachers introduced the instructional methods to the class.

In Treatment A, the direct instruction format was familiar to all. For the team practice and STL classes, however, some procedures were new and had to be learned by teachers and students. Working with the regular curriculum, teachers introduced the practice format and worked on team-building. STL classes began earning the certificates and recognition associated with cooperative learning formats. In early April, the teachers reported that the proposed curriculum needed to be adjusted to meet the needs of their students. They made revisions accordingly, to produce a version of the unit that preserved the essential lessons within a simplified presentation scheme. In mid-April, after spring break, all teachers began using the heuristics curriculum and taught continuously for 20 school days, about five weeks elapsed time. In mid-May, all teachers administered the post-test. (Within-unit tests and the post-test were scored by teachers and became the basis for regular grades. The post-tests were then collected and scored independently by the researchers to assure common standards for analysis of outcomes.).

Curriculum materials were provided for all students. The materials included warm-up problem sets emphasizing functional math skills, problem-solving lesson pages and practice problem sets, and homework problems tied to the lesson. Specially written tests were developed to assess student progress throughout the study. Teachers were given lesson guides and answer keys, as well as supplies to produce their own materials as needed.

Teachers were observed in each of their designated classes during the study to evaluate implementation. The observer was familiar with the heuristic strategies and the three methods. She was used by the teachers as problem-solver and coach.

The control group studied problem-solving as a topic integrated into the regular math curriculum. They took the post-test at the same time as students in the experimental groups, in mid-May.

Measures. For purposes of this study, a post-test based on the heuristic strategies in the experimental curriculum was administered to all students. In addition, fall and spring scores on the Maryland Functional Math Test (MFMT), routinely administered to all seventh graders in the district, were collected. The MFMT includes problem-solving, but does not highlight it. The Fall MFMT score established the relative entering achievement levels of students in each class.

Results

Post-test problem-solving scores were converted to z-scores, statistically adjusted for Fall MFMT scores, and then used in individual-level analysis of variance. Not surprisingly, students in all three treatments scored significantly better on the problem-solving post test than did those in the untreated control group. However, there were no significant differences among the three experimental treatments. (See Table 1.)

Table 1: Adjusted Post-Test Scores in Problem Solving (PS)

Treatment Group	Adjusted Score	Standard Deviation
PS Direct Instruction	0.03	0.85
PS Team Practice	0.17	0.83
PS Student Team Lrng	0.05	0.85
Regular Curriculum	-0.70	0.83

Differences between problem solving and regular curriculum groups are significant beyond the 0.001 level. Differences among problem-solving groups are not significant.

Discussion

The results of this study suggest that teaching problem-solving heuristics does increase the problem-solving abilities of seventh graders. However, neither the team practice nor the student team learning strategy added to the effectiveness of direct instruction in use of heuristics. This finding is in line with Davidson's (1985) conclusion that for math problem-solving, cooperative learning has been shown to be neither more nor less effective than more traditional methods.

However, several aspects of this study may have contributed to a failure to find significant differences among the treatments. First, it seems likely that the absence of significant differences in achievement outcomes may in this case simply reflect inadequate differentiation among treatments. Working with a new set of lessons for the first time, teachers seemed preoccupied with the challenge of interpreting the content to students. They did not seem to implement the three treatments with the kind of fidelity that was needed to create three significantly different learning situations that might have resulted in significantly different outcomes.

Despite a two-week warm-up period in which to accustom them to the general structure of their designated treatment, students took some time to learn to function effectively in the team practice and STL situations and teachers took some time in finding ways to coach them in group skills. Observer notes record two findings of interest: early visits were characterized by lots of teacher questions on implementation; and early lessons in every treatment consisted mostly of teacher-directed presentation and practice. The teachers showed in many ways that they were willing to implement the research design faithfully and eager to see how different strategies worked, but apparently needed more lead time than was provided to develop effective instructional support for the team practice and STL treatments, which were new to them.

Furthermore, early in the study teachers using the direct instruction model with individual practice mentioned that their students did use each other as resources when trying to solve hard practice problems. If most of the teachers were spending most of their time on the presentation and guided practice components and were struggling to master the new skills involved in using team practice or team recognition, and many of the students in the direct instruction groups were in effect practicing with peer assistance, then few differences in outcomes might be observed among treatments. As actually implemented, the treatments may not have been sufficiently different to generate different outcomes.

Second, the students in all treatments performed significantly better than control students, which might imply that using heuristics with any good method is better than using approaches to teaching problem-solving without heuristics. However, the control students were taught by one teacher who was not devoting class time exclusively to teaching problem-solving by any method. Thus it is possible that the significantly lower scores on the problem-solving test simply reflect that teacher's ineffectiveness or the ineffectiveness of teaching problem-solving within the context of other math topics, rather than in a concentrated dose. However, the students in the control group were among the highest in entering achievement and had been exposed to similar strategies throughout the year -- evidently they had the wit and the opportunity to learn, but they did not learn. Though the study cannot be said to prove beyond a doubt that tne heuristic approach is relatively more powerful than others, it does suggest some effectiveness.

Finally, there is the response of the teachers to the questions and potential solutions raised by the study. In meetings during the period of implementation, teachers reported that in their team practice and STL classes they were hearing students actually talk to each other about math problems. Though as a group they had the usual range of reservations about trying a new teaching strategy, teachers were impressed by student reactions to teamwork. Furthermore, teachers frequently commented on the changes they observed in student attitudes toward problem solving as the weeks passed. They seemed to feel that students were investing more in learning to become problem solvers. Students appeared to attack word problems more hopefully as well as more effectively.

When the study ended, they wrote a proposal and won a grant to work with the district math supervisor to expand the curriculum and coach their peers in its use. The new curriculum was designed to require the student team learning format, which they decided was best suited for teaching math prob :m-solving, even though they had found it harder to start up the STL activities than they had anticipated. Their work is now part of the regular math curriculum.

Such anecdotes cannot be construed as evidence of success -- too many novel and appealing programs are adopted for their charms rather than their merits. However, they add to the support for raising the questions of this study in a context free from some of its limitations. Data that more clearly illuminate the issues might be generated in a replication that improves implementation in several ways. Among the most important improvements might be to train teachers long enough and observe teachers often enough to assure that they are skillful in treatment procedures well before they introduce the experimental lesson content.

Conclusion

Considerable evidence has demonstrated that in many areas of the curriculum, among them math computation, students learn more and feel better about themselves and their competence in cooperative learning situations. The evidence in the area of math problem-solving has not been compelling, however -- neither cooperative learning nor any other strategy has shown consistent, positive effect. While the results of this study do not provide the missing evidence about how to promote more competence in math problem-solving, they do provide some insight into where the evidence might be. The questions of the study remain unanswered -- but they also remain important. Research that transcends this study's limitations in addressing those questions can make a critical contribution to math education.

References

Davidson, N. (1985). Small-group learning and teaching in mathematics: A selective review of the research. In R. E. Slavin, S. Sharan, S. Kagan, R. Hertz.Lazarowitz, C. Webb, and R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Dolan, D., and Williamson, J. (1983). *Teaching problem-solving strategies.* Reading, MA: Addison-Wesley.

Johnson, L.C. and Waxman, H.C. (1985). Evaluating the effects of the "Groups of Four" program. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Lester, F.K. (1980). Research on mathematical problem solving. In R. Shumway (Ed.), *Research in Mathematics Education* (pp. 286-323). Reston VA: NCTM.

Noddings, N., Gilbert-MacMillan, K., and Leitz, S. (1983). What do individuals gain in small group problem solving? Paper presented at the Annual Meeting of the American Educational Research Association, Montreal.

Peterson, P.L. and Janicki, T.C. (1979). Individual characteristics and children's learning in large-group and small-group approaches. *Journal of Educational Psychology*, 71, 677-687.

Peterson, P.L., Janicki, T.C., and Swing, S. (1981). Ability x treatment interaction effects on children's learning in large-group and small-group approaches. *American Educational Research Journal*, 18, 453-473.

Polya, G. (1957). *How to solve it.* (Second Edition). New York: Doubleday.

Polya, G. (1965). *Mathematical Discovery (volume II).* New York: John Wiley.

Robertson, L. (1982). Integrated goal structuring in the elementary school: Cognitive growth in mathematics. Unpublished doctoral dissertation, Rutgers University.

Romberg, T, and Wearne, D. (1975). *Romberg-Wearne Mathematics Problem Solving Test.* Madison, WI: Wisconsin Research and Development Center, University of Wisconsin.

Silver, E.A. (1985). *Teaching and Learning Mathematical Problem Solving: Multiple Research Perspectives.* Hillside, NJ: Erlbaum.

Slavin, R.E. (1983a). *Cooperative Learning.* New York: Longman.

Slavin, R.E. (1983b). When does cooperative learning increase student achievement? *Psychological Bulletin*, 94, 429-445.

Slavin, R.E., Leavey, M, and Madden, N.A. (1984). Combining cooperative learning and individualized instruction: Effects on student mathematics achievement, attitudes, and behaviors. *Elementary School Journal*, 84, 409-422.

Slavin, R.E. Madden, N.A., and Leavey, M. (1984). Effects of team assisted individualization on the mathematics achievement of academically handicapped and nonhandicapped students. *Journal of Educational Psychology*, 76, 813-819.

Szetela, W. (1982). *Mathematics Problem Solving Activities*. Palo Alto, CA: Dale Seymour.

Vygotsky, L.S. (1978). *Mind in society*. M. Cole, V. John-Steiner, S. Scribner, and E. Souberman (Eds.). Cambridge, MA: Harvard University Press.

Webb, N. (1985). Student interaction and learning in small groups: a research summary. In Slavin et al (Eds), *Learning to cooperate, cooperating to learn*. New York: Plenum.

Webb, N. and Kenderski, C. (1984). Student interaction and learning in small groups and whole class settings. In P. Peterson, L.C. Wilkerson, and M. Hallinan (Eds.), *The social context of instruction: Group organization and group processes*. San Francisco: Academic Press.