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ABSTRACT

The study was designed to investigate: (1) the relative effectiveness of three techniques for teaching verbal problem solving to general education mathematics students in a junior college; and (2) the relationships between various student variables and problem-solving ability after treatment. Three classes (N=72) at Florida College were randomly assigned to treatment: flow charting (as employed in programming problems for a computer), heuristic (a method built around Polya's approach), or structure questioning (an approach designed by Phillips and Soriano). Pretests were given at the beginning of spring semester, followed immediately by the treatment for ten class periods. Posttests were given during the next two periods, with retention tests 11 weeks later. Significant increases were found from pre- to posttest for all three groups on typical problems. There were no significant differences between groups on posttests and retention tests. Three significant aptitude-treatment interaction effects were found, favoring the heuristic treatment for low achievers. No significant differences between groups were found from pre- to posttest on the novel problems; however, scores between groups were significantly different on the pretests. It was concluded that any of the three techniques might be used to aid junior college students' problem-solving ability. (MNS)

The Effects of Three Instructional Techniques on the Problem-Solving Ability of General Education Mathematics Students at the Junior College Level

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The present study was designed with two major purposes: 1) to investigate the relative effectiveness of three instructional techniques (Flow charting, Heuristic, and Structured questioning) for teaching problem solving to general education mathematics students at the junior college level, and 2) to investigate the relationships between various student variables and problem-solving ability after treatment. Students and treatments were randomly assigned to groups. Dependent means t-tests showed significant increases ($p<.001$) from pre- to posttest for all three groups on typical verbal problems. Analysis of covariance showed no significant differences between groups on posttests and retention tests. Three significant aptitude-treatment interaction effects were also discovered ($p<.05$).

I. Objectives

This experimental study was designed with two major purposes: 1) to investigate the relative effectiveness of three different techniques for teaching verbal problem solving to general education mathematics students at the junior college level, and 2) to investigate the relationships between several variables (sex, class, Nelson-Denny Reading scores, SAT math and verbal scores, SRA IQ scores) and problem-solving ability and/or improvement in problem-solving ability after treatment.

II. Historical perspective and educational importance of the study

The importance of developing problem-solving ability among the general populace was highlighted recently in the National Council of Mathematics' Agenda for Action (1980). Of the eight recommendations for school mathematics for the 1980s, the first and most important one was that "problem solving be the focus of school mathematics in the 1980s." Further, the National Council of Supervisors of Mathematics (1977) has defined problem-solving as one of the ten basic skill areas in school mathematics. The results of the second and third National Assessment of Educational Progress (NAEP) illustrate vividly that the goal is not being attained. The NAEP mathematics assessment results were based on the performance of a representative sample of over 70,000 9-, 13- and 17-year olds in 1978 and over 46,000 in 1982 who took a carefully developed set of about 500 exercises that assessed important objectives of the mathematics curriculum. The inescapable conclusion to be derived from the results is that many students at all three levels lack even the most basic problem solving skills. (Carpenter, 1980; Hill, 1980)

Kilpatrick (1971 and 1978) and Hatfield (1978) were both critical of past research in problem solving, but both found inconclusive evidence that certain procedures which will improve problem-solving ability can be learned and that certain teaching techniques can be employed to teach these procedures. A review of the literature revealed that there is sufficient evidence to hypothesize that any of the three treatment could bring about a significant improvement in problem-solving ability. The factors chosen to investigate in a correlation study with problem-solving ability were also chosen on the basis of previous research which indicated that they may account for a significant amount of the variance in problem-solving ability.

III. Methods

The researcher taught verbal problem solving to three classes of General Education Mathematics at Florida College using three different instructional techniques. The students were randomly assigned to the classes at registration and the classes were randomly assigned to the treatments (Flow charting (F), Heuristic (H), and Structured questioning (S)). The F group was taught problem solving using a flow charting method as is employed in programming problems for a computer. The H group was taught using a method built around Polya's heuristic approach to problem solving. The S group was taught using a "structured questioning" approach designed by Phillips and Soriano.

Pretests were given at the very beginning of the spring semester, followed immediately by the treatment period, consisting of ten class periods of 50 minutes each (three weeks and one day). Posttests were given during the next two class days after the treatment period. Retention tests were given during the last week of the semester (11 weeks later).

The differences in the scores on the pretest and the posttest were taken as a measure of the improvement in problem-solving ability. Differences between the scores on the "typical" tests were taken as a measure of the effectiveness of the treatment, and differences between the scores on the "novel" tests were taken as a measure of transfer of learning as result of treatment. Differences between the scores on the retention tests and the posttests were taken as a measure of retention of learning.

The students in each group were also given a questionnaire at the end of the instructional treatment period to assess their individual reactions to the method of problem solving they were taught.

IV. Data source and analysis

Instruments. The researcher designed two sets of pretests, posttests and retention tests to measure problem-solving ability. Experts in mathematics education were asked to attest to the content validity of each instrument relative to the purposes of the present experiment. One set, consisting of eight verbal problems on each of the three tests, was to measure problem-solving ability on typical verbal problems, like those discussed during the treatment period. The other set, consisting of six verbal problems per test, was to measure problem-solving ability on novel verbal problems. The problems were of a general class of problems that could be solved using arithmetic and/or algebraic techniques involving simple linear or, at most, quadratic equations. The total score was determined by the number of correct answers. Items were not weighted and no partial credit was given.

Sample. The sample consisted of three classes enrolled in General Education Mathematics at Florida College for the spring semester, 1983, as described above. For the F group n=27, for the H group n=25, and for the S group n=20. There were no significant differences between groups in terms of SAT verbal and math scores, Nelson-Denny Reading scores or SRA IQ scores. The distributions of the three groups in terms of mathematical background, and community size of hometown were also similar.

Data Analysis. A two-tailed, dependent means t-test was used to test the null hypothesis for each treatment separately with regard to improvement in problem-solving ability, effectiveness of treatment, transfer, and retention. Analysis of covariance (ANCOVA), with the pretests as the covariates, was used to test the omnibus null hypothesis for the three group means on the "typical" and "novel" posttests. A similar ANCOVA was used to test the omnibus null hypothesis for the retention tests, using the posttests as the covariates. Multiple regression techniques were used to examine the posttests and the retention tests (using each student variable separately as the covariate) for significant interactions between the treatments and each student variable. A Pearson correlation matrix between the four, continuous student variables and the six tests was calculated.

V. Results and conclusions

The results of the research showed the following with regard to the typical verbal problems:

1. The average scores on the posttest were significantly higher than the average scores on the pretest for all three instructional techniques.
2. The average scores on the retention test were at least as high as the average scores on the posttest for all three instructional techniques. For the flow charting technique they were significantly higher.
3. There were no significant differences between the group means on the pretest (oneway ANOVA), the posttest (ANCOVA using pretest as covariate), or the retention test (ANCOVA suing posttest as covariate).
4. The results of the "typical" tests correlated most highly with SAT mathematics scores and IQ scores.
5. There were three significant aptitude-treatment interactions - Group with Nelson-Denny Reading scores on the posttest, Group with SAT verbal scores on the posttest, and Group with SRA Primary Mental Abilities IQ scores on the posttest (AVCOVA with student variables as covariates). In each case the heuristic group had the strongest disordinal interaction with the other two groups.

The ATI results were unexpected in view of previous research. According to Moore's (1980) study, students with high reading ability obtained higher problem-solving scores after the heuristic treatment. Students with low reading ability benefitted more from the algorithmic treatment. In the present study, students with low Nelson-Denny Reading scores, low SAT verbal scores and low SRA IQ scores benefitted more from the heuristic treatment than the other, more algorithmic, treatments. The following is offered as a possible reason for the ATIs observed in the present study. The poorer students may have been more willing to pursue the heuristic technique to its conclusion since often the problem could be solved without employing all of the suggested heuristics. They may have found it less tedious. (The responses on the questionnaire tend to support this.) The better students, on the other hand, were more willing to force themselves to stay on task in the flow charting and structured questioning techniques than the poorer students.

With regard to the novel verbal problems, there were no significant differences between the average scores from pre- to posttest for any of the three treatments. There was a significant difference between the three group means on the pretest, thus any conclusions comparing the three techniques on the posttest and retention test would be invalid.

All three techniques can be effective in improving students' self confidence and attitudes toward mathematical verbal problems. No direct efforts were made to improve the students' self confidence of attitudes. It is reasonable to conclude, therefore, that these results were a direct outgrowth of the students' increased success in attacking and solving verbal problems.

The results described in 1 and 2 above are the bases for the major conclusions drawn from this study: Any of the three techniques can be successfully employed to improve significantly the problem-solving ability of general education mathematics students at the junior college level on typical verbal problems, and this improved ability is maintained over a long period of time. The present study provides no basis for selecting one technique over the others, although there is some evidence (the three ATIs described above) that the heuristic technique would be more successful with students who have lower reading, SAT verbal and SRA IQ scores. In any case the present research supports the view that problem solving skills can be taught and learned even among poorer mathematics students.