DOCUMENT RESUME

ED 139 611 SE 022 256

AUTHOR Berkowitz, Melissa S.; Szabo, Michael
TITLE Individual and Dyadic Problem Solving on a Computer Based Task as a Function of Mental Ability.
PUB DATE Mar 77
NOTE 17p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (50th, Cincinnati, Ohio, March 22-24, 1977)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS College Science; *Educational Research; *Grouping (Instructional Purposes); Higher Education; *Instruction; *Problem Solving; *Science Education; *Student Ability
IDENTIFIERS Research Reports

ABSTRACT

This study examined the effects of mental ability upon problem-solving processes of individuals and dyads confronted by complex science problems. A 2 X 3 design was used, with two levels of grouping: individuals and dyads, and with three levels of mental ability: high (H), high plus low (HL), and low (L). The experimental problem was to solve the riddle of the frozen wooly mammoth, which required the subject to hypothesize, request information, and form new hypotheses. An interactive computer assisted instruction system was used as a data source, feedback mechanism, and monitoring system. Eighty undergraduates participated. The dependent variables were: number of hypotheses; number of data requests; number of data matches; total times; time expended for hypothesis; and proportion of positive, negative, and neutral information. A between-subjects ANOVA was used to analyze data. Results showed that H dyads requested significantly more data than H individuals, while L dyads received significantly fewer data matches than L individuals and HL dyads. H individuals spent significantly less time in the problem space than H dyads, and L individuals spent significantly more time than dyads. L subjects received significantly fewer instances of positive information, more neutral information, and spent more time reading neutral information than HL subjects of H subjects. H subjects received significantly more positive information, less neutral information, and spent less time reading the neutral information. (Author/DT)

ED139611

Individual and Dyadic Problem Solving on a Computer Based Task as a Function of Mental Ability

by

Melissa S. Berkowitz
The Pennsylvania State University

and

Michael Szabo, Ph.D.
The Pennsylvania State University

A paper presented at the meeting of the National Association for Research in Science Teaching, Cincinnati, March 1977.

SE 022 252

This study examined effects of level of mental ability upon the problem solving process of individuals and pairs of individuals engaged in a complex, open-ended, data-rich problem.

Rationale

Maier (1971), has recommended the development of innovative instructional systems which will enable students to have greater responsibility for their academic progress. Maier's suggestion inspires an investigation of student problem solving behavior. Problem solving facility enables the student to formulate solutions to problems within as well as outside of the classroom. The provisional nature of instruction necessitates the development of a large degree of student self-sufficiency (Bruner, 1964); therefore, instruction should increasingly stimulate the active participation of the learner.

Science educators have adopted problem-solving approaches for the instruction of science as a process of inquiry (Anderson, 1967). A variety of step-wise instructional models have evolved which generally direct the student through the formulation of the problem, hypothesis, research, results and conclusion (Wallas, 1926; Dewey, 1933; Polya, 1954; Bloom, 1956; Suchman, 1962; Guilford, 1967; Eberle, 1973). Anderson (1967) has suggested that scientific research rarely proceeds in the linear fashion indicated by these models. Bruner (1962) has emphasized the importance of intuitive thinking as a problem-solving process which defies prescribed procedures. A closer examination of specific problem-solving processes is needed to clarify the use of problem solving as an instructional strategy.

Glaser (1976) has suggested that studies of problem-solving processes may reveal instructional strategies useful for teaching "learning how to learn" techniques. Resnick and Glaser (in press) suggest that certain problem-solving

processes may resemble the processes involved in learning without the complete instruction of the teacher. Research in problem solving processes has the potential for instructional design which incorporates psychological theory and educational practice (Glaser, 1976).

Innovative instructional systems may be devised with plans for alternative student-teacher or student-student interactions. Goldshmid (1971) describes the learning cell which is a dyadic unit of two students who mutually teach and learn. Little research has emerged on this type of peer-assisted relationship in problem-solving activities.

Reid, Palmer, Whitlock and Jones (1973) suggest an examination of the benefits of student interaction on problem-solving tasks with specific attention to the individual characteristics which are functioning in such interactions. Reid et al. suggest that research be undertaken to determine the differential effects of one versus two students working on a problem. They also suggest an investigation of individual characteristics which combine in the dyadic unit to determine which type of dyad functions most effectively in a problem solving situation. The present study investigated a segment of the issues raised by Reid et al. by focusing on the individual characteristic of mental ability level and its influences upon performance of dyads and individuals engaged in an open-ended, data-rich problem.

Literature Review

Maier, in a summary of studies conducted prior to 1963, found group problem solving to be superior, inferior, as well as equal to individual problem solving. These conflicting findings apparently are the result of comparisons of a variety of group compositions, problem types and analysis procedures. Perhaps a strict generalization about the quality of group versus individual problem-solving performance cannot be made.

Steiner (1966) has proposed several models to predict group performance based on the type of task assigned. In Steiner's Complementary Task Model each individual possesses some unique resources not possessed by other group members. The combination of these complementary resources enables the group performance to surpass the performance of the same individuals working alone. Lorge and Solomon (1955) have devised two mathematical models which suggest that the superiority of the group is a function of the increased probability that one of its members can solve the problem, which in turn is primarily a matter of ability. These three models suggest that group members pool complementary information enabling the group to exceed the performance of its best individual. If however, the key to successful problem solving is this factor of ability, it would appear that a group of low ability members may pool divergent information inhibiting a successful solution attempt. The models predict an interaction between grouping (group versus individual) and ability level.

Lorge and Solomon (1953) did not specify the type of ability responsible for the difference between group and individual performance. A reasonable possibility is general mental ability, defined as skill with symbolic operations.

The research exploring the relationship between mental ability and problem solving has yielded inconclusive results. Raaheim and Kaufmann (1974) have suggested that factors aside from ability such as range of task difficulty, knowledge of implements, presence of certain tools, experience, or motivation can confound the relationship between problem solving and ability. In a study which attempted to control for a number of these extraneous varibles, Raaheim and Kaufmann found a significant positive relationship between mental ability and success in problem solving tasks. Rhoades (1977) using the mammoth

simulation, found that mental ability was a significantly discriminating variable in relation to selected problem-solving criteria when used with other predictors in a multiple discriminant analysis function. This provided the rationale for selection of a measure of mental ability in the present investigation.

Fluency

A variety of problem solving process criteria is necessary to analyze complex problem solving. One process criterion measure used particularly in studies of creative problem solving has been fluency or number of responses generated for a given problem. Renzulli, Owen and Callahan (1974) have suggested that increased fluency is one of the goals of group problem solving. Torrance (1970), with specific attention to individual and dyadic problem solving, found increased fluency in the dyadic condition.

Efficiency

Another process criterion measure is efficiency which can be measured in terms of time expended formulating the problem and total time interacting with the problem. Torrance (1970), Husband (1940) and Taylor and Faust (1952) have suggested that group problem solving time should be less than one half the time spent by individuals to be efficient.

Data Usage

Shaw (1932), Thorndike (1938), and Tate and Stanier (1964) have suggested that the use of positive and negative information be measured. In a study by Rhoades, Sunshine and Szabo (1977), time spent considering positive and negative data was significantly related (through multiple discriminant function analysis) to intelligence and hypothesis formation skills. Shulman and Elstein (1975) noted the apparent disregard of negative data in complex decision making involving medical personnel.

On the basis of the Lorge and Solomon Model, Steiner's Complementary Task Model, and the problem-solving process criteria suggested above, it was expected that interactions exist between grouping (individual vs. dyads) and mental ability level on criterion measures of fluency, efficiency and data usage.

Methodology

The design of this study was a 2 x 3 analysis of variance with two levels of grouping (individuals and dyads) and three levels of mental ability (above average, above & below average and below average) as determined by scores on the Otis Quick Scoring Mental Ability Test (Otis, 1954).

Subjects

The subject pool was composed of 121 volunteer undergraduate students enrolled in Educational Psychology courses. Ninety students were selected to be in the study proper as determined by their scores on the Otis Quick Scoring Mental Ability Test (Otis, 1954).

Variables

The independent variables included: 1) grouping (individual vs. dyadic cooperative) during solution attempt and, 2) mental ability as described above.

The following problem solving criteria were used as dependent variables in this study: (a) fluency measures of: number of hypotheses, number of data requests and number of data matches; (b) efficiency measures of: total time participating in the problem solving session and the average time spent devising each hypothesis; and (c) the data usage measures of: proportions of positive, negative and neutral information received and average time spent examining positive, negative and neutral information. A particular data piece was determined to be positive if it supported a hypothesis posed by the

subjects,negative information contradicted a posed hypothesis and neutral information served as background material or was completely unrelated to a hypothesis.

Apparatus and Procedures

The Otis Quick Scoring Mental Ability Test Form Gamma-Am used to determine a mental ability score for each subject. The subjects were classfied as above average (score $\geq$118), average (112$<$score$<$118) or below average (score$\leq$112). The above average and below average subjects were randomly assigned to one of six conditions in which they were to pursue the experimental task: (1) above average (AA) individuals, (2) one half above and one half below average (A&B) individuals (3) below average (BA) individuals, (4) AA dyads, and (5) A&B dyads and (6) BA dyads. Ten individuals or dyads were randomly assigned to each condition (See Figure 1).

The experimental task was to solve the riddle of the frozen wooly mammoth simulation developed by Riban and Szabo (1968) and programmed by Rhoades and Szabo (1977). An IBM 1500 interactive computer system with cathode ray terminals was used as a data source, feedback menhanism and monitoring system which tracked the subjects problem solving activity.

During the problem session the subjects were confronted with the problem to be solved in printed format. The confrontation emphasizes the bizarre circumstances surrounding one of the mammoth finds. The subjects were requested to develop hypotheses for the problem and request data from the simulation program to verify or dispute the hypothesis posed. During the solution attempt the simulation provided various content-free heuristics (based upon sets or chains of data presented) and evaluated the conclusions posed (Szabo and Rhoades, 1977). After two hours, the subjects ended the problem session at their will by forming final conclusions.

Each variable in the three categories of dependent variables (fluency, efficiency and data usage) was analyzed by a 2 x 3 Between Subjects Analysis of Variance.

Fluency Criteria

Significant disordinal interactions between grouping and ability level were observed for number of data requests [$F(2,54)=4.29, p<.05$] and number of data matches [$F(2,54)=3.55, p<.05$]. Follow-up tests, using the Tukey WSD technique revealed above AA dyads requested significantly more data than AA individuals. The mean scores for this interaction are displayed in Figure 2. Follow-up tests for number of data matches indicated BA dyads received significantly less data matches than BA individuals and A&B dyads. The means of this interaction are displayed in Figure 3.

The results of the analysis of variance with the fluency criterion variable of number of hypotheses indicated nonsignificant effects.

Efficiency Criteria

The results of the analyses of the efficiency criteria variables indicated a significant disordinal interaction for the total time participating in the problem session [$F(2,54)= 4.98, p<.05$]. Follow-up tests indicated AA individuals spent significantly less time in the problem space than AA dyads. BA individuals spent significantly more time than BA dyads. The means of this interaction are displayed in Figure 4. The results of the analysis of the average time devising each hypothesis yielded nonsignificant results.

Data Usage Criteria

On the analyses of the data usage variables nonsignificant results were found for the proportion of negative information presented and average time spent examining positive and negative information. Significant main effects

of mental ability were found for proportion of positive information presented [F (2,54) = 13.19, p<.05] and neutral information presented [F(2,54) = 13.19, p .05]. Follow-up tests of these two variables indicated that AA subjects received significantly more positive and less neutral data than A&B subjects, who in turn received more positive and less neutral data than BA subjects. The analysis of the average time spent examining neutral information yielded significant main effects of grouping [F(2,54) = 4.64, p < .05] and mental ability [F(2,54) = 7.56, p < .05]. Dyads considered neutral data for longer periods of time than individuals. AA subjects and A&B subjects spent significantly less time on neutral data than BA subjects.

Discussion

The unique design of Mammo simulation facilitated the examination of problem-solving processes predicted from the work of researchers who used single solution tasks in their studies (Shaw, 1932; Thorndike, 1938; Husband, 1940; Harootunain & Stanier, 1960; Tate & Stanier, 1964.). Therefore, with few studies resembling the present problem task, this study was exploratory in method as well as theory.

The present study posed that when the ability level of the group is above average the performance will be superior to that of individuals and that when ability level is below average the performance will be inferior to that of individuals (Lorge & Solomon, 1955; Steiner, 1966). This expected interaction of grouping and mental ability level was confirmed by certain measures of fluency and efficiency. Individuals searched for, received and consumed information differently than dyads as a function of their mental ability levels. Generally, the interactions suggest that the BA dyads requested and received less information and participated for less time than BA individuals. AA dyads requested and received more information and participated for a longer period.time than AA individuals.

The performance of the A&B dyads generally resembled that of the AA dyads.

The measures of number of hypotheses and average time devising each hypothesis yielded nonsignificant results. Perhaps the differences between hypotheses of AA and BA individuals and dyads do exist using the criterion of hypothesis quality in addition to or in place of quality. Rhoades (1977), using the Mammo simulation in a multiple discriminant analysis study, found the quality of hypotheses, in conjunction with other variables had significant positive discriminant coefficients for classifying good and poor problem solvers.

For measures of data usage the ability level of the subject appears to be the determinant of the type of data received and the length of time it was processed. Perhaps higher ability subjects are more capable of requesting information which specifically relates to their hypotheses. The analysis of the average time reading neutral information yielded results consistent with the research of Levine (1969); that is, BA subjects spent significantly more time examining data which negated their hypotheses. Perhaps the neutral data were studied for background information which the BA subjects did not bring to the problem session.

The results of the present study indicate significant differences between individuals and dyads, organized by mental ability level, in certain processes with theoretical relation to problem solving. Future investigations should devise guidelines for "good" problem-solving techniques using realistic open-ended tasks. These investigations would enable researchers to translate the results of process studies, such as the present, into instructional strategies.

Mental Ability Level	C_1 Individual	C_2 Dyad
Above Average Otis $\geq$ 118	Above N = 10	Above + Above N = 10 pairs
Above Average 1/2 $\geq$ 118 Below Average 1/2 $\leq$ 112	Above N = 5 Below N = 5	Above + Below N = 10 pairs
Below Average Otis $\leq$ 112	Below N = 10	Below + Below N = 10 pairs

Figure 1. 2 x 3 Design of Present Study

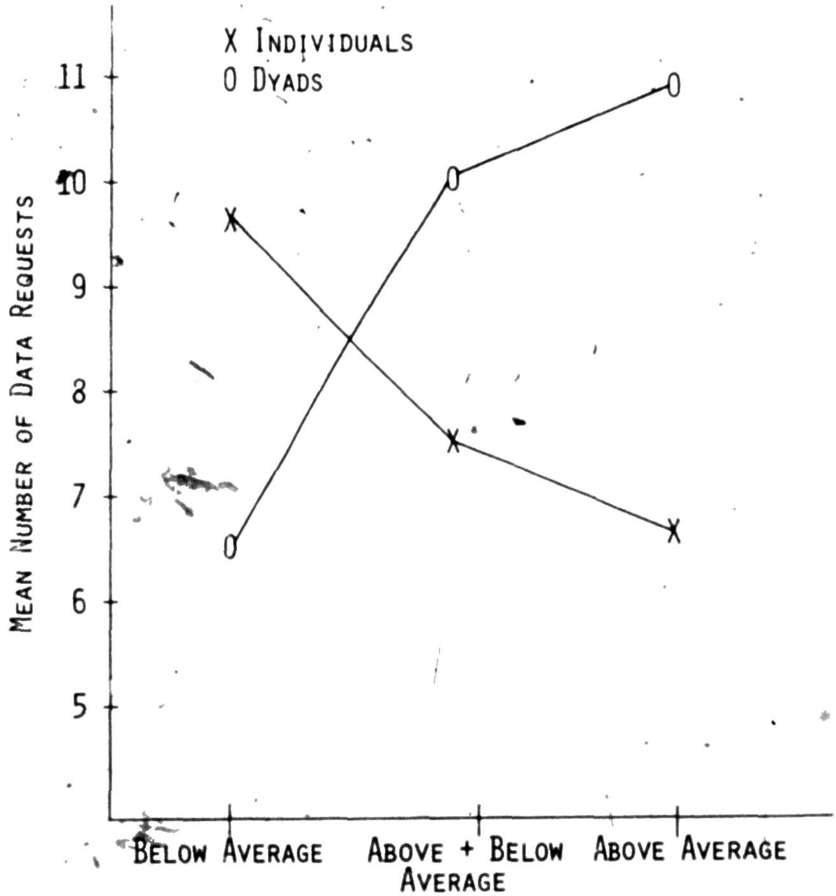

Figure 2. Grouping by Mental Ability Level Disordinal Interaction for Mean Number of Data Requests

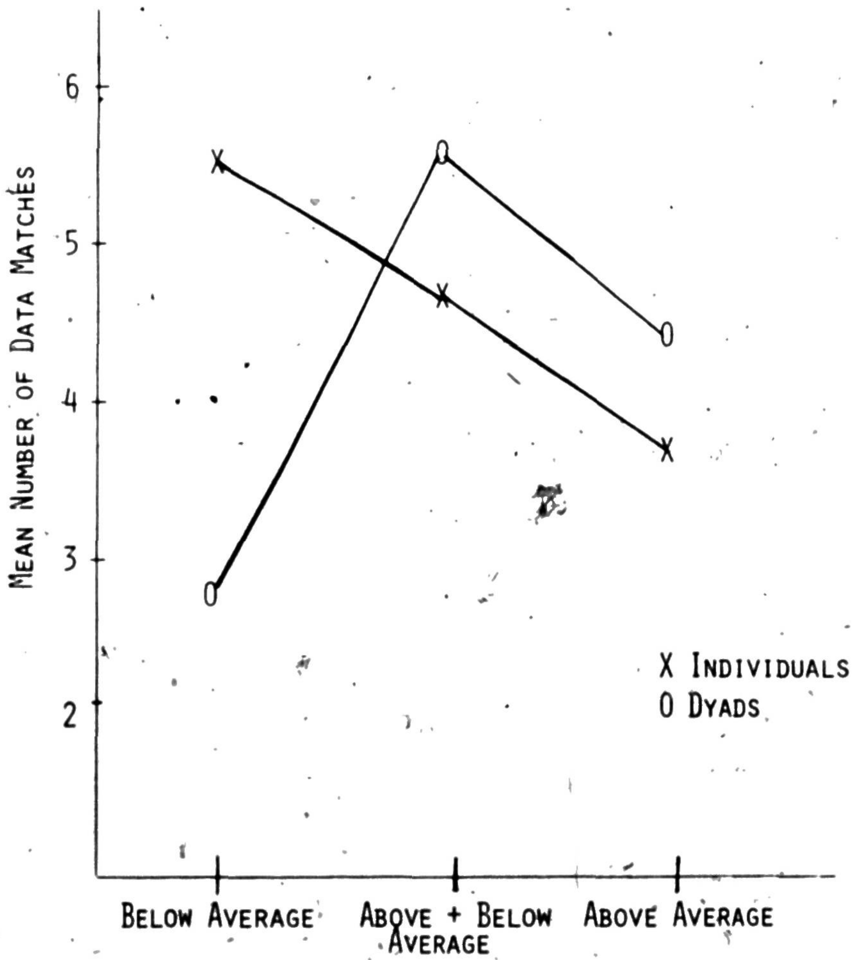

Figure 3. Grouping by Mental Ability Level Disordinal Interaction for Mean Number of Data Matches

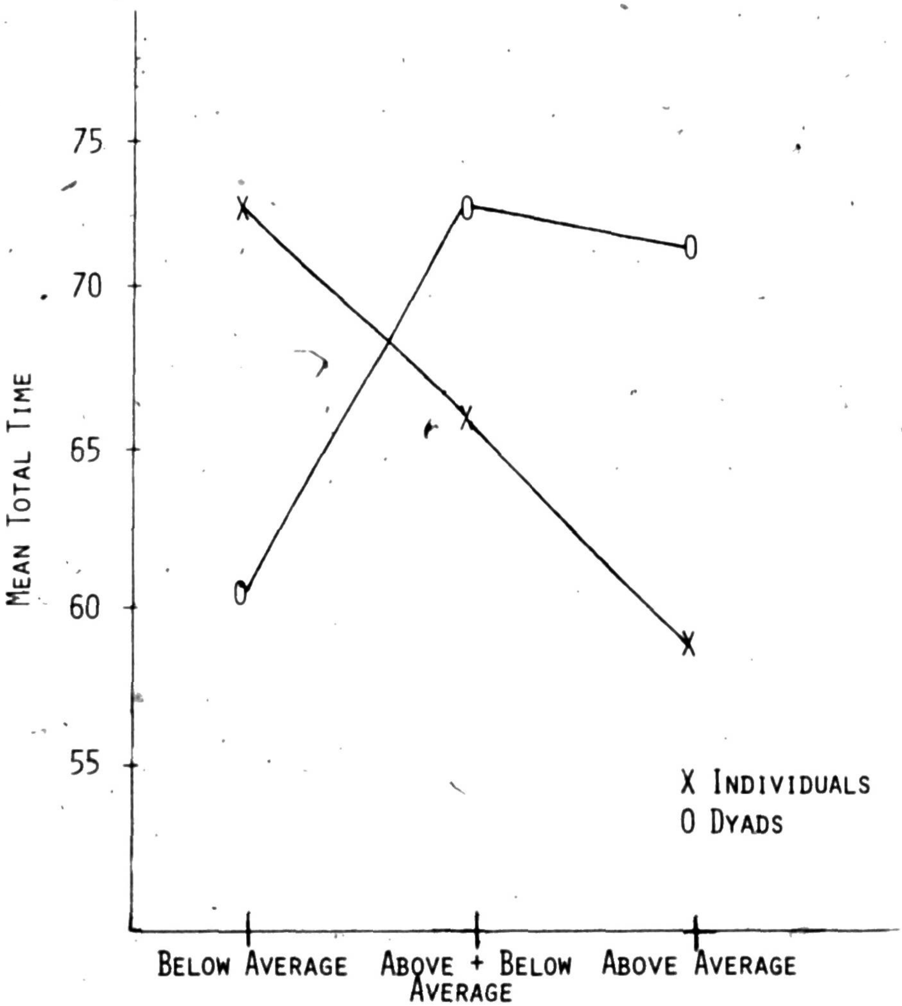

Figure 4. Grouping by Mental Ability Level Disordinal Interaction for Mean Total Time

References

Anderson, H. O. Problem solving and science teaching. School Science and Mathematics. 1967, 67, 243-251.

Bloom, B. S. Taxonomy of Educational Objectives, Handbook I: Cognitive Domain. New York: Longmans, Green & Co., 1956.

Bruner, J. S. The Process of Education. Cambridge: Harvard University Press, 1962.

Dewey, J. How We Think. New York: Heath Co., 1933.

Eberle, R. Problem solving modes of classroom instruction. Educational Leadership. 1973, 30, 726-728.

Glaser, R. Components of a psychology of instruction: toward a science of design. Review of Educational Research. 1976, 46, 1-24.

Goldshmid, M. L. The learning cell: an instructional innovation. Learning and Development. 1971, 2, 1-6.

Guilford, J. P. Three faces of intellect. American Psychologist. 1967, 17, 469-479.

Harootunian, B. & Stanier, B. Relationship of certain selected variables to problem solving ability. Journal of Educational Psychology. 1960, 51, 326-333.

Husband, R. W. Cooperative versus solitary problem solution. Journal of Social Psychology. 1940. 11, 405-409.

Levine, M. Latency-choice discrepancy on concept learning. Journal of Experimental Psychology. 1969, 82, 1-3.

Lorge I. & Solomon, H. Two models of group behavior in the solution of eureka-type problems. Psychometrika. 1955, 20, 139-148.

Maier, N. F. Innovation in education. American Psychologist. 1971, 26, 722-725.

Maier, N. F. Problem Solving Discussions and Conferences: Leadership Methods and Skills. New York: McGraw-Hill, 1963.

Otis, A. Otis Quick Scoring Mental Ability Test, Gamma. New York: Harcourt Brace & World, 1954.

Polya, G. How to Solve It. Princeton: Princeton University Press, 1954.

Raaheim, J. S., Owen, S. V. & Callahan, C. M. Fluency, flexibility and originality as a function of group size. Journal of Creative Behavior. 1974, 8, 107-113.

Resnick, L. B. & Glaser, R. Problem solving and intelligence. In L. B. Resnick (Ed.) The Nature of Intelligence. Hillsdale, N. J.: Lawrence Erlbaum Assoc., in press.

Reid, J. B., Palmer, R. L., Whitlock, J. & Jones, J. Computer-assisted instruction performance of student pairs as related to individual differences. Journal of Edcuational Psychology. 1973, 65 (1), 65-73.

Rhoades, T. A Multiple Discriminant Analysis Study of Complex Problem Solving Ability in a Computer Based Learning Environment. Unpublished doctoral dissertation, The Pennslyvania State University, 1977.

Rhoades, T., Sunshine, P. & Szabo, M. A Multiple Discriminant Analysis Study of Complex Problem-Solving Activity in a Computer Based Environment. A paper presented at the meeting of the American Educational Research Association, New York City, April 1977.

Riban, D. & Szabo, M. Development and Preliminary Utilization of a Model for the Teaching of Data Utilization in Synthesis. Unpublished manuscript, Purdue University, 1968.

Shaw, M. E. Comparison of indiyiduals and small groups in the rational solution of complex problems. American Journal of Psychology. 1932, 44, 491-504.

Shulman, L. S. & Elstein, A. S. Studies of problem solving, judgement and decision making: implications for educational research. In F. Kerlinger (Ed.). Review of Educational Research III. Itasca: F.E. Peacock, 1975.

Steiner, I. D. Models for inferring relationships between group size and potential group productivity. Behavioral Science. 1966, 11, 273-283.

Suchman, J. R. Inquiry training model. In B. R. Joyce & M. Weil (Eds.), Models of Teaching. Englewood Cliffs: Prentice-Hall, 1972.

Szabo, M. & Rhoades, T. Complex problem solving experience for undergraduates via computer technology. Journal of Creative Computing. 1977, Jan-Feb, 70-73.

Tate, M. W. & Stanier, B. Errors in judgement of good and poor problem solvers. Journal of Experimental Education. 1964, 32, 371-376.

Taylor, D. W. & Faust, W. L. Twenty questions: efficiency in problem solving as a function of size of group. Journal of Experimental Psychology, 1952, 44, 360-368.

Thorndike, R. L. The effects of discussion upon the correctness of group decision when the factor of majority influence is allowed for. Journal of Social Psychology. 1938, 9, 343-362.

Torrance, E. P. Influence of dyadic interaction on creative functioning. Psychological Reports. 1970, 26, 391-394.

Wallas, G. The Art of Thought. New York: Harcourt, Brace & World, 1926.