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ABSTRACT

These experiments tested the hypothesis that an instructional strategy involving guided discovery will promote meaningful learning of problem solving concepts by activating an assimilative set during learning. In order to investigate the effect of discovery training and concrete manipulation, preschool children were given training in one to one correspondence. In the first study (involving 19 subjects) a discovery method was compared to a matched expository method, both of which involved active manipulation of objects. The second study (involving 24 subjects) replicated the first study using different materials and included a third group (observation training) in which subjects did not manipulate objects. The learning outcomes were evaluated by tests of short-term recall, short-term transfer, long-term recall and long-term transfer. Performance on the posttests administered by a "blind" experimenter revealed a pattern in which groups did not differ on short-term recall but the discovery group excelled on far transfer (conservation) and delayed recall. The effect of guided discovery on the acquisition of broader learning outcomes was discussed. (MS)

Guided Discovery for Children's Learning of Number Concepts

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Abstract

In two experiments, 43 pre-schoolers learned the concept of one-to-one correspondence to identical behavioral criteria by matched discovery, expository or observation methods of instruction. Performance on a subsequent posttest, administered by a "blind" experimenter, revealed a pattern in which the groups did not differ on short-term recall but the discovery group excelled on far transfer (conservation) and delayed recall. The effect of guided discovery on the acquisition of broader learning outcomes was discussed.

Guided Discovery for Children's Learning of Number Concepts

Discovery methods of instruction received much attention during the 1960's. The promise of "meaningful" learning outcomes, superior transfer and longer retention were particularly attractive to educators (Bruner, 1961; Shulman & Keislar, 1966). However, consistent empirical support for the claims failed to materialize (Wittrock, 1966), and there has been a lack of agreement on how to define the concept of discovery or relate it to a useful theory of instruction (Strike, 1975).

More recently, Mayer (1975) has suggested a theory of instruction based on the idea that meaningful learning depends on the satisfaction of at least three conditions: (1) Reception -- the learner must be presented with and pay at-ention to the to-be-learned material. (2) Availability -- a set of related experiences must be available in the learner's long term memory to serve as an assimilative set. (3) Activation -- the assimilative set must be actively processed during learning. According to this view, discovery methods of instruction might be supposed to have their main effect on condition 3 by encouraging subjects to actively search and process their existing meaningful knowledge and relate it to on-going learning.

There are several situations in which discovery methods of instruction might fail to achieve the goal of broader learning outcomes. Even though condition 3 may be satisfied, if the subject fails to discover the to-be-

learned principle (condition 1) no learning will occur. This situation provides one interpretation of the many instances in which "guided discovery" results in more learning or better transfer than pure discovery (Gagne & Brown, 1961; Wittrock, 1966; Forgus & Schwartz, 1957). In addition, discovery methods which encourage active search of existing knowledge (condition 3) will be of little value if no useful related knowledge exists in memory (condition 2). For example, Mayer, Stiehl & Greeno (1975) found that although all subjects could learn to solve simple binomial probability problems by discovery, only the group that received pretraining in the basic underlying concepts performed better on transfer to more integrative problems. Finally, Egan & Greeno (1975) have produced evidence that discovery and rule methods of instruction may result in different patterns of transfer performance with rule subjects excelling on near transfer and discovery subjects excelling on far transfer problems; this finding is consistent with the idea that rule subjects added the material as presented (satisfying only condition 1) while discovery subjects integrated the new material within existing knowledge (conditions 1, 2 and 3).

There is some evidence that instructional methods which serve to activate a learning set (condition 3) may be particularly important for children. Several investigators have studied the effects of discovery methods for instructing children in mathematical concepts (Peters, 1970; Olander & Robertson, 1973; Anastasiov, et. al., 1970). The results, as

with those cited above, are contradictory. Much of the discrepancy may be accounted for by the non-uniform manner in which the learning outcomes have been evaluated. Also the concept of discovery itself is rather vague and has included a wide range of very diverse instructional strategies.

Another manner in which the assimilative set might be activated during learning is to allow the learner to manipulate concrete materials. Piaget (1965) has claimed that mathematical concepts can only be learned if the subject has an opportunity to manipulate real "concrete" objects. Television programs such as Sesame Street which attempt to teach basic mathematical concepts do not allow such active manipulation to occur, and would not result in meaningful learning according to this view. There is some evidence that learning of number concepts on Sesame Street may not be as effective (Bogatz & Ball, 1971) as more rule-oriented televised sequences (Henderson, Swanson & Zimmerman, 1975), although neither allows for active manipulation of objects. A major problem confronting the discovery issue is to clearly separate "discovery from "active manipulation" in order to ascertain the contributions of each to learning.

In order to investigate the effect of discovery training and concrete manipulation, pre-school children were given training in one-to-one correspondence. In the first study, a discovery method was compared to a matched expository method, both of which involved active manipulation of

objects. The second study replicated the first study using different materials, and included a third group (observation training) in which subjects did not manipulate objects. The learning outcomes were evaluated by tests of short-term recall, short-term transfer, long-term recall, and long-term transfer.

The assimilation theory cited above suggests several predictions that were tested in the present study. Discovery subjects should connect the new skill (one-to-one correspondence) with existing concepts while expository subjects might simply add the new behavior without integrating it. Since both groups learned to the same criterion, performance on short-term retention should be similar for both groups; however, the broader learning outcome of the discovery group should result in superior performance on problems requiring transfer of the learned material to novel situations, and long-term retention. A more straightforward idea is that since both groups reach the same level of learning, they have learned the same thing and should perform similarly on all tests. In addition, the present experiments will provide information on whether training with manipulation (discovery and expository training) results in broader learning than training involving no manipulation (observation training).

Experiment 1

Method

Subjects. The subjects were 19 children between the ages of 3 years 6 months and 5 years 1 month who attended a private nursery school

near Santa Barbara, California and who failed a pretest for one-to-one correspondence (out of a larger group of 62 pretested children). They came primarily from white, middle-class and upper middle-class homes, and written parental permission was obtained for all subjects.

Design. Subjects were divided into two groups, with 10 subjects in the discovery training group and 9 subjects given expository training. All subjects were tested on the same four posttests so that comparisons by type of posttest are within subject comparisons.

Procedure. Each subject participated individually in four sessions, sitting opposite the experimenter at a small table in the nursery school. Following each session, a small colored star was given as a reward for participating.

In session 1, a pretest for one-to-one correspondence was administered to all subjects. Those who passed were eliminated from the study. In session 2 (two days later) those who failed the pretest were given one of two training programs for one-to-one correspondence. Subjects were randomly assigned to treatments except that an attempt was made to equate groups for age and sex. In session 3 (5 to 7 days later) five recall tests and five transfer tests were administered. In session 4 (14 days later) three delayed recall tests and a test for conservation of number were administered. The experimenter who administered the tests did not know which training the subjects had received.

Materials. The materials consisted of 12 red and 12 blue poker chips (1 1/2 inches in diameter), 12 small red poker chips (approximately 3/4 inch diameter), 12 wooden blocks (1 inch sides), and a 10 x 14 inch piece of white cardboard separated lengthwise by a 3/8 inch ridge. In addition, standard data forms and a package of colored gummed stars were used.

Pretest. For the pretest six blue poker chips were placed on the experimenter's side of the board, next to the ridge, and equally spaced. The subject was given the red chips with the instructions, "Now you put just as many red poker chips on your side. Make it so there are just as many red ones as blue ones." Following the subject's response, a second trial with seven poker chips was given. The criterion for passing the pretest was a correct response on either or both of the trials.

Expository Training. One blue poker chip was placed on the experimenter's side of the board, next to the ridge with instructions for the subject to watch carefully. One red poker chip was then placed directly oppsite the blue one, and the experimenter said: "See, I'm putting just as many poker chips on your side as there are on my side." The red one was then removed and the subject was asked to do it. If the subject did not correctly place a red chip opposite the blue one, the experimenter demonstrated again. This continued until the subject responded correctly, The procedure was then repeated with 2, 3, 4, 5, 6, and 7 poker chips. Each error was corrected by the experimenter demonstrating again how to place the red chips. The training ended after the subject had correctly

matched 7 blue poker chips with 7 red ones.

Discovery Training. One blue poker chip was placed on the experimenter's side of the board, next to the ridge, with the instructions: "Now you put just as many red poker chips on your side." If the subject did not do it correctly, then the experimenter demonstrated, as in the expository training. After one chip was correctly matched, two chips were presented.

If the subject did not correctly match two chips, the experimenter did not demonstrate immediately, but returned to one chip, letting the subject match one chip again. If the subject still did not match two chips correctly the second time, then the experimenter demonstrated how to do it. This same procedure was then repeated with 3, 4, 5, 6, and 7 poker chips. Each time the subject made an error, the experimenter returned to the previous number, with demonstrations only as needed the second time around. The training ended after the subject had correctly matched 7 blue poker chips with 7 red ones.

Recall tests. Each subject was tested on the numbers 5. 6. 7. 8, and 9 with a procedure identical to that of the pretest. For the numbers 8 and 9, the board was lengthened by adding an extra part to it.

Transfer tests. Five tests involving one to one correspondence were administered in which the conditions were slightly different from the training. The instructions to the subjects were always to put "just as many" objects on their side as there were on the experimenter's side

of the board. The tests were as follows:

1. Different objects: tan, one-inch wooden blocks were used on both sides of the board, instead of poker chips. One trial was given using 6 blocks.
2. Smaller chips: the subject was given small (3/4 inch diameter), red chips while the experimenter's blue ones remained the same large size. One trial was given with 7 chips.
3. Chips close together: the experimenter placed the chips in a row next to the ridge with no spaces between them. The regular large-sized chips were used. One trial was given using 6 chips.
4. Two rows of chips: the experimenter placed 7 chips on the board in two rows. One row was next to the ridge and contained 4 chips, while the other was further back and contained 3 chips, opposite the spaces between the first 4, making a zigzag pattern. One trial was given.
5. Piles of chips: the experimenter's chips were placed in 3 piles of 2 chips each, next to the ridge, with the top chips covering about half of the bottom chips. One trial was given.

Delayed recall tests. The subjects were tested on the numbers 5, 7, and 9 with a procedure identical to that of the pretest.

Conservation test. The experimenter first presented six blue chips with instructions identical to those of the pretest. Any errors were corrected. Once there were two rows of chips in correct one to one correspondence, the experimenter lengthened the row of red chips by spreading them out so that they surpassed the row of blue chips by one at each end. The subjects were then asked: "Are there still just as many red ones as blue ones, or does one of us have more?" The subjects' answers were written down. The same procedure was repeated with 7 chips, except that the red chips were pushed together, instead of spread out, so that they were surpassed by one blue chip at each end.

Results

Thirty-four subjects passed the pretest and were eliminated from the study. Of the 28 subjects who failed, 19 completed the training and tests. There were therefore 9 drop-outs. Two of the children dropped out after the pretest, two during discovery training, 3 during expository training, and 2 after completing the expository training but before the tests.

Of the 19 subjects who completed the training and tests, 10 were in the discovery group and 9 in the expository group. The average age of the discovery group subjects was 4 years and 1 month (48.8 months),

while the expository group subjects averaged 4 years and 0 months in age (47.9 months). There was no significant difference between the mean ages of the 2 groups ($t = 0.32$, $df = 17$, $p > .20$). The discovery group contained 7 girls and 3 boys, while the expository group contained 3 girls and 6 boys.

The tests were scored as follows: each subject received 4 different scores between 0 and 100 reflecting the percentage of correct answers in each of the 4 types of tests: short-term recall, transfer, delayed recall, and conservation test. The means on each posttest for the two groups appear in Table 1.

Two separate analyses of variance were computed on the data. The first had one between subjects factor (the type of training received) and one within subjects factor (the type of test). The effect of the type of training was significant ($F = 4.66$, $df = 1/17$, $p < .05$), with the discovery group performing better than the expository group, overall. The effect of the type of test was also significant ($F = 28.7$, $df = 3/51$, $p < .001$). The group by test interaction did not quite reach significance at the .05 level ($F = 2.28$, $df = 3/51$, $p < .1$).

The second analysis of variance also had one between subjects factor (type of training), identical to the first analysis, but had two within subjects factors: delay of test (1 week delay and 3 weeks delay), and type of test (recall and transfer). For purposes of this analysis, the conservation test was considered a transfer test. The effects of

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Insert Table 1 about here

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delay of test and type of test were both significant ($F = 134.3$; $df = 1/17$, $p < .001$, and $F = 84.2$, $df = 1/17$, $p < .001$, respectively). The groups by delay interaction was significant ($F = 56.99$, $df = 1/17$, $p < .001$), with the expository training group performing comparatively worse in the 3 weeks tests than in the 1 week tests. The delay by type interaction was also significant ($F = 4.84$, $df = 1/17$, $p < .05$).

Experiment 2

Method

Subjects. The subjects were 24 children between the ages of 3 years 3 months and 5 years and 0 months who attended two private schools near Santa Barbara, California, and who failed a pretest for one-to-one correspondence (out of a larger group of 53 pretested children). The children from school A (a half-day nursery school) came primarily from white, middle-class and upper middle-class homes, while the children from school B (a day care center) came from both white and black, middle-class homes. Written parental permission was obtained for all subjects.

Design. There were three between subject groups: 9 subjects served in the discovery group, 8 subjects served the expository group and 7

subjects served in the observation group. Since all subjects took the same five posttests, comparisons by type of posttest are within subject comparisons.

Procedure. Each subject who failed the pretest participated individually in four sessions sitting opposite the experimenter at a small table in the school. No rewards were given for participating.

In session 1 a pretest for one-to-one correspondence was administered to all subjects. Those who passed were eliminated from the study as in Experiment 1. In session 2 (1 to 14 days later) those who failed the pretest were given one of three training programs for one-to-one correspondence. Subjects were randomly assigned to treatments except that an attempt was made to equate groups for age, sex and school attended. In session 3 (5 to 7 days later) the recall test, transfer test, and conservation test were given. In session 4 (14 days later) the same recall and conservation tests were administered as in session 3.

Materials. Materials consisted of 12 small, plastic, black and white panda bears; 12 small, plastic, partly eaten apples, 12 red and 12 blue standard poker chips as used in Experiment 1, and the board and data sheets used in Experiment 1.

Pretest. The children were first familiarized with the materials, learned to name each object and were shown the bear "eating" one of the apples. Six bears were placed on the experimenter's side of the board, next to the ridge, equally spaced, and facing the subject, with the

instructions: "Now you put just as many apples on your side. Make it so there are just as many apples as bears." Following the subject's response, a second trial with seven bears was given. The criterion for passing the pretest was a correct response on either or both of the two trials.

Discovery and expository training. The discovery training and the expository training were identical to study I with the exception that bears and applies were used instead of poker chips.

Observation training. Observation training was done in the form of a game in which the experimenter placed various numbers of bears on one side of the board and applies on the other side, and the subject had to judge each time whether it was done "right" or "wrong". "Right" was the appropriate answer for a correct one-to-one correspondence, i.e., the same number of applies as bears. Objects were placed in the following manner, each pair beginning with the number of bears on the experimenter's side of the board: 1 and 1, 2 and 2, 2 and 3, 3 and 2, 3 and 3, 4 and 5, 4 and 4, 5 and 4, 5 and 5, 6 and 5, 6 and 6, 7 and 6, and 7 and 7. The apples (with the exception of the extra one or the missing one) were each placed directly opposite a bear. In order to familiarize the subjects with the same vocabulary as was used in the other two training methods and the tests, during each trial the experimenter said: "I'm going to put just as many apples as bears here. Look, are there just as many apples as bears? Did I do it right or wrong?" If the subject made an incorrect judgment, the experimenter simply corrected by saying, "No, I did it right (or wrong) this time,"

and proceeded to the next problem. The last six problems were repeated over again in the same order as many times as needed until six successive correct judgments occurred.

Recall test. The recall test was identical to the pretest and was administered at both test sessions.

Transfer tests. Transfer tests were administered only at the first test session. There were four different tests involving one-to-one correspondence in which the conditions were slightly different from the training. The instructions to the subjects were always to put "just as many" objects on their side as there were on the experimenter's side of the board. The tests were as follows:

1. Different objects: blue and red poker chips were used instead of bears and apples. One trial was given using seven poker chips.
2. Two rows of bears: the experimenter placed seven bears on the board in two rows of four and three forming a zigzag pattern. One trial was given.
3. Bears close together: the experimenter placed six bears in a row next to the ridge with no spaces between them. One trial was given.
4. Piles of bears: six bears were placed in three piles of two bears each, next to the ridge. One trial was given.

These four tests were equivalent to transfer tests 1, 4, 3, and 5, respectively, of study 1.

<u>Conservation test</u>. The conservation test was identical to the conservation test of study 1 except that bears and apples were used instead of poker chips. Two trials were given at both test sessions.

Results

Sixteen subjects passed the pretest and were eliminated from the study. Of the 37 subjects who failed, 24 completed the training and tests. There were therefore 13 drop-outs. Two of the children were dropped after the pretest because of inability to understand the instructions, two were dropped because of inability to learn the observation training, and two left school before completion of the study. The others dropped out of their own accord (refused to play): three after the pretest, one after discovery training, one after expository training, and two after observation training.

Of the 24 subjects who completed the training and tests, nine were in the discovery group, eight in the expository group, and seven in the observation group. The mean ages of the subjects were 4 years and 2 months for the discovery group, 4 years and 1 month for the expository group, and 3 years and 11 months for the observation group (49.8 months, 49.0 months, and 46.7 months, respectively). T-tests revealed no significant differences between these means. The discovery group contained 3 girls and 6 boys, while the expository group contained 4 girls and 4 boys, and the observation group 4 girls and 3 boys.

The tests were scored as follows: each subject received five different scores between 0 and 100 corresponding to the percentage of correct

answers for each of the five types of tests: recall, transfer and conservation tests one week after training, recall and conservation tests three weeks after training. The group means for the five tests are shown in Table 2.

Two separate analyses of variance were computed on the data. The first had one between subjects factor (the type of training received) and one within subjects factors (the type of test). Overall, the discovery group performed better than the expository group, which, in turn performed better than the observation group, but the effect of the type of training did not quite reach significance at the .05 level ($F = 2.876$, $df = 2/21$, $P < .1$). The effect of the type of test was highly significant ($F = 29.63$, $df = 4/84$, $p < .001$), but there was no group by test interaction ($F = 1.03$, $df = 8/84$, $p > .20$).

A second analysis of variance was done with the data from the recall and conservation tests only. There were two within subjects factors: delay of test (1 week and 3 weeks), and type of test, and one between subjects factor: the type of training. The effect of type of training was significant ($F = 4.09$, $df = 2/21$, $p < .025$). The effect of type of test was also significant ($F = 60.99$, $df = 1/21$, $p < .001$), and the 3-way interaction between groups, delay and type of test almost reached significance at the .05 level ($F = 2.85$, $df = 2/21$, $p < .1$). This finding generally replicates the main finding of Experiment 1. None of the other interactions were significant.

In addition to these analyses, individual comparisons were done pairwise between the three groups for each type of test, using Fischer's exact probability method. The subjects were categorized according to whether they passed or failed the various tests. The criterion for passing was at least one out of the two trials correct for the recall and conservation tests, and at least three out of the four trials correct for the transfer tests. The discovery group performed significantly better than the observation group on the conservation test given 1 week after training ($p < .05$). At the three weeks delay the difference between the discovery and observation groups was marginally significant for both the recall and conservation tests ($p < .1$). There was also a marginally significant difference between the discovery and expository groups on the conservation test given one week after training ($p < .1$). There were no other significant differences between the groups.

Conclusions

These results provide some evidence concerning the effects of discovery and active manipulation of objects on children's learning of number concepts. If this study had used only a posttest based on mastery of the presented information (i.e., only a recall test) there would have been no evidence of differences among the training groups in either Experiment 1 or Experiment 2. However, when posttests are given that include far transfer such as conservation tests, important differences

emerge: in particular, the discovery group performs relatively better that the expository group on far transfer while both groups perform at similar levels for short-term recall. This finding suggests that discovery instruction resulted in a broader learning outcome. A third interesting piece of information is that, in Experiment 2, there were no reliable differences in the performances of the expository and observation groups. Hence, without discovery, the active manipulation of objects seemed to have little positive effect.

These findings are consistent with the idea that the discovery procedure encouraged subjects to activate their existing cognitive structures concerning number concepts, and to assimilate the new information to form a broader learning outcome. Subjects in the expository and observation treatments apparently were more likely to add the new behaviors to memory without connecting them to related ideas. It should be noted that the discovery procedure developed for these studies was guided in the sense that subjects continued on the problem until they reached a level of mastery.

One important pedagogic implication of this finding is that equivalent mastery on a behavioral level such as was displayed by each of the treatment groups does not guarantee equivalency in "what is learned". Experiment 1 and the replication provided by Experiment 2, help extend earlier work on discovery (Egan & Greeno, 1975) to a new subject population (pre-schoolers) and provide a step in our understanding of the cognitive effects of discovery.

Table 1:

Mean Percentage of Correct Responses by Two Training Groups on Four Types of Tests

Instructional Method	One Week After Training		Three Weeks After Training	
	Recall	Transfer	Delayed Recall	Conservation
Discovery Group	96	72	100	56
Expository Group	80	64	71	19

Table 2:

Mean Percentage of Correct Responses by

Three Training Groups on Five Types of Tests

Instructional Method	One Week After Training			Three Weeks After Training	
	Recall	Transfer	Conservation	Delayed Recall	Conservation
Discovery	78	53	44	100	28
Expository	63	50	6	75	6
Observation	71	39	0	57	0

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