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Instruction of young children on number conservation and unidimensional classification

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Kindergartners and first graders who were lagging behind their peers in cognitive development were offered either of two forms of special instruction during the fall semester. One group was given learning set training on two forms of simple classification and on number conservation. The other group was given more conventional instruction on letter, word, number, and arithmetic skills. The children who were taught classification and conservation made gains on verbal and arithmetic measures that matched those of the children who were taught verbal and arithmetic skills directly.

The state of cognitive development expressed by measures of classification, seriation, and conservation abilities at age five is predictive of school achievement in early elementary school (see Silliphant, 1983, for a summary). These cognitive operations depend at least in part on learning. Hypothetically, then, if remedial instruction in classification, seriation, and conservation were offered to 5-year-olds who were laggard in their development, gains in academic achievement might result.

Learning set methods, which work well in inducing concept development, consist essentially of a variety of simple problems that can be solved through application of the same abstract principle (Gelman, 1969). Abbreviated learning sets have been used in two instances to teach classification, seriation, and conservation operations to 5-year-olds who were not doing well in kindergarten (Pasnak, 1987; Pasnak, McCutcheon, Holt, & Campbell, 1991). In the latter study, gains in mathematical and verbal comprehension were noted. Similar instruction for children who were mildly mentally retarded was also associated with verbal achievement gains (Campbell, McCutcheon, Perry, & Pasnak, 1988; McCormick, Campbell, Pasnak, & Perry, 1990; Pasnak, Campbell, Perry, & McCormick, 1989). The present field experiment was intended to test this method with a very exacting control procedure.

The subjects were kindergartners and first graders from a school serving a very mixed, immigrant population living in unaffluent neighborhoods. The children who attended the school spoke 23 different dialects among them. All who were enrolled in the school spoke sufficient English to function there, as determined by school evaluations. Some of these children may have been handicapped in communication by the variety of languages spoken by peers and adults, and by being schooled in English rather than their native languages. Many of these children did not enter school until the first grade, and hence they were chronologically more mature than the kindergartners studied by Pasnak (1987) and Pasnak et al. (1991).

An active control group was used in this experiment. That is, the control children received as many special lessons as did the experimental children, but their lessons were on topics recommended by their teachers, not on concrete operations. Hence, the null hypothesis was that both types of instruction would produce equal gains in academic achievement. Alternatively, either the control instruction that was focused directly on academic material or the experimental instruction that was aimed at enhancing achievement as a result of increasing cognitive competence might produce greater academic gains.

METHOD

Subjects

The subjects were 10 kindergarten and 20 first-grade students, of the ages 5 to 7, enrolled in a northern Virginia suburban school district. The children were selected by their respective teachers from two first-grade classes, one morning kindergarten class, and one afternoon kindergarten class. Each teacher chose the 5 (kindergarten) or 10 (first-grade) children who fell into the lowest portion of their class according to the teacher's estimate of their classroom performance and subjectively assessed ability. Half of those selected were children designated as having "English as a second language."

Two of the kindergarten children did not receive parental permission to participate. The other children were matched within each class according to individual scores on three pretest measures, and a child from each pair was randomly assigned to experimental or control groups. One male first grader from the control group and the female with whom he was matched in the experimental group moved away during the year. In addition, a male first grader from the experimental group moved away; therefore, the data for the female with whom he was matched was not analyzed. Eight of the remaining control children were male, 4 female; 3 were White, 2 Black, 3 Hispanic, 2 Vietnamese, 1 Turkish, and 1 Arabic. Ten of the remaining experimental children were male, 2 female; 5 were White, 1 Black, 2 Hispanic, 2 Cambodian, 1 Pakistani, and 1 Chinese. All the children were treated in accordance with the ethical

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principles of the American Psychological Association (APA, 1981) throughout the experiment.

Materials

Tests used for pretesting and posttesting were the Stanford Early School Achievement Test (SESAT) subscales on stories (a verbal comprehension measure) and mathematics, and the Metropolitan Achievement Test (MAT) scale on Mathematics Concepts.

The Orientation Training Set contained 20 problems, each consisting of four identical items. In each problem, three of the four items were oriented one way and the fourth another way. Specific examples of items used were: plastic pigs, horses, and sheep; sticks of gum; small Barbie plastic tennis rackets, shoes, and hangers; and wooden numbers and shapes.

The Successive Classification Training Set contained 20 form problems and 20 size problems. Each problem in each set consisted of four items, three of which were identical and a fourth that differed slightly in either form or size. Specific examples of items used for form problems were: plastic shells and horse heads; wooden letters, numbers, and shapes; rubber squares, triangles, and flowers; plastic paper clips and plastic silverware. Examples of items used for size problems were: metal picture hanger hooks, plastic stars, plastic clips, metal bells, silk flowers, metal hardware pieces, hair bands, metal paper clips, wooden sticks, and plastic clothes hooks.

The Verbal Discovery of Class Training Set contained 20 problems, each consisting of the names of four familiar objects. Three of the items had a common function, type, or characteristic, and one was different. Specific examples of the four named objects include: apple, *ball*, lemon, grape; *lamp*, wheel, trunk, hood; celery, carrot, *bread*, lettuce; *lipstick*, pen, pencil, paint brush; hammer, *book*, nail, screw; car, truck, motorcycle, *horse*; boot, *glove*, sandal, tennis shoe; finger, foot, head, *shirt*; ice cube, popsicle, *coffee*, ice cream.

The Conservation Training Set consisted of 15 problems of 7 to 35 items each. Each problem was a forced-choice task involving identical items arranged in two rows. The training items were: 7 safety pins, 9 plastic clips, 11 plastic sticks, 13 plastic hair pins, 15 plastic jacks, 17 plastic stars, 19 plastic flowers, 21 dried lima beans, 23 metal bobby pins, 25 colored wire paper clips, 27 pennies, 29 metal clasps, 31 dried kidney beans, 33 plastic paper clips, and 35 plastic antishorts.

Instruments used in control group instruction included alphabet flashcards; mimeographed worksheets on spelling, math, and sentence structure; sequence story cards (groups of five cards that depicted some act such as brushing one's teeth; the cards had to be placed in sequential order); paper coins; a math bingo game; and spelling flashcards.

Procedure

All children were pretested with their classmates on the SESAT and MAT. Those in each class whose scores matched most closely were designated as pairs, and they were randomly assigned to experimental and control groups. The members of each pair were considered to be yoked; they each received the same number of lessons, and when instruction of a child in the experimental group was concluded, that of the yoked control child was also concluded. The children in the experimental group were instructed in small groups of 5 or less for 15-min sessions, 2 or 3 days per week, on classification by orientation, successive classification, and number conservation, in that order. The 20 orientation problems presented to the children represented varying degrees of difficulty. In each problem, four identical items were presented, with three facing in the same direction and the fourth facing in a different direction. As the other children in the group watched, a child was instructed to look at the items very carefully and point to the one that was pointing differently. The child was coached and rewarded with praise and stickers for correct answers. For each session, each child was presented with a problem that had already been mastered and then presented with a more difficult problem. Instruction in classification by orientation continued until all the children in the experimental group had mastered all the problems.

In successive classification, it was essential that the child not be able to see the stimulus objects simultaneously. For this purpose, two large boxes were used, each with a hole cut in the side through which the child could insert his/her hand. A sleeve was attached to each hole so that peeking was impossible. The child was allowed to take time handling the objects so that tactile discriminations could be made. For 20 sets of four items each, one item differed from the other three only in size; for 20 more sets, one item differed only in form. The aim of this task was to teach the child to compare at least three items in succession before making a choice. The children were encouraged to develop a system to keep track of the comparisons made (e.g., place similar items to one side and dissimilar items to another side). Once a child had developed a system, the other children were instructed to pay special attention to this child in order to help them in developing their own systems. Once most of the children in a group had mastered this task, they were allowed to work with and assist one another while the instructor began conservation training with 1 or 2 other children during each session. At this time, the instructor also began presenting verbal discovery of class problems at the beginning of each session.

For verbal discovery of class problems, the names of four objects were read to the group and the children were asked to tell which one was different, and why the other three were similar to each other. Explanations for decisions were sought from the children and developed through coaching. Two verbal discovery problems were presented in each session, beginning with 1 old problem that had been mastered and then followed with 1 new problem until all 20 problems were mastered.

For number conservation training, orderly rows of objects were compressed or expanded while the children watched. Comparisons of rows to which objects were added or subtracted, with or without compression or expansion of the row, were used to teach the children that number was constant unless an addition or subtraction occurred. The instruction relied heavily on providing explanations to the children and on inducing explanations from them in support of their judgments. The number of items in each row was gradually increased from 4 to 17, using the materials described previously.

Praise was given to each child for industry and attention during each session, and every child was awarded a sticker at the end of the session. All experimental children ultimately solved all training problems.

The control children also received instruction in small groups of 5 or less, in sessions matching those of the experimental children in timing. The control children in kindergarten classes received instruction on the alphabet, using alphabet flash cards. The children were instructed to identify the letter and then, as they mastered this task, to volunteer a word that started with the letter.

The control children in each first-grade class worked on several different tasks, chosen on a daily or weekly basis by each teacher. Mimeographed worksheets were used often to instruct the children on spelling skills, word sounds, sentence structure, mathematical skills of addition and subtraction, and the identification of words and the objects to which they referred. In three sessions, the children were each given a set of five sequence story cards that they had to place in proper order to tell the story that the cards depicted. Each child was then instructed to tell the particular story to the rest of the group.

Paper coins were used on four occasions to instruct the children in monetary concepts. Each child was provided with a bag that contained paper pennies, nickels, dimes, quarters, and fifty cent pieces. The children were instructed to use the coins in one or more combinations to display a given sum of money.

A math bingo game, which involved simple mental addition or subtraction problems, and spelling flash cards were also used for four sessions each.

These tasks were varied day by day to maintain the interest of the children, who were consistently rewarded verbally for correct answers. At the end of each session, all children received small stickers.

As children in the experimental group completed their instruction, that of the yoked children in the control group was terminated; the total number of sessions ranged from 48 to 52 for all pairs. Eight weeks after the instruction was concluded, the children were retested on the SESAT and MAT subscales.

RESULTS

A 2×2×2 (instruction × grade × time) analysis of variance was computed for each of the dependent vari-

Table 1
Description and Analysis of Scores on SESAT Verbal Subscale

	Fall		Spring	
	M	*SD*	*M*	*SD*
Experimental				
Kindergarten	12.25	2.99	19.25	2.06
First grade	17.50	2.56	19.38	6.16
Combined	15.75	3.65	19.33	5.03
Control				
Kindergarten	9.50	4.66	18.25	2.87
First grade	14.75	3.92	16.25	5.01
Combined	13.00	4.73	16.92	4.38

	Analysis of Variance			
	df	*MS*	*F*	*p*
Source				
Grade (G)	1	49.59	1.31	>.05
B/N grades	10	37.79		
Instruction (I)	1	61.76	3.37	>.05
G×I	1	3.01	.16	>.05
W/N G×I	10	18.34		
Time (T)	1	243.84	25.49	<.001
G×T	1	102.09	10.67	<.01
W/N G×T	10	9.57		
I×T	1	1.26	.19	>.05
G×I×T	1	3.01	.45	>.05
W/N G×I×T	10	6.72		

ables; *instruction* refers to the experimental versus control group comparison. The different error terms reflect the differing correlations between scores made by the same children over time, scores made by matched children in the two conditions, and scores made by unmatched children in different grades.

The verbal measures were analyzed as raw scores, since there are no percentile measures for this SESAT subscale. There was significant improvement from pretest to posttest, and the kindergartners improved significantly more than the first graders, as was shown by the significant interaction of grade and time (see Table 1). The former improved by 7.88 points, the latter by only 1.69. The difference between experimental and control groups approached but did not reach significance on a two-tailed test ($p = .096$).

Parallel analyses for both mathematics measures showed significant differences between grades and significant improvement from pretest to posttest. There were no interactions. These results are shown in Tables 2 and 3.

DISCUSSION

The results common to all three measures—significant improvement over time and generally higher scores for first graders than for kindergartners—are what would be expected. The significant interaction of grade and time on the verbal measure—kindergartners improving more than first graders—is more of a surprise. In part, it may reflect the level of the SAT used—the SESAT is formulated more for kindergartners than for first graders. However, even the first graders made scores far below the ceiling for the test, so the interaction may suggest that greater gains are possible on first encounter with formal schooling.

The very marginal difference in scores of experimental and control children on this measure surely represents random variation, not an instruction effect. It was present on the pretest, before any instruction occurred, in spite of matching and randomization, and it never changed much.

The most important outcome of this research is that the children who were taught classification and conservation performed every bit as well on the academic posttest measures as those who were taught academics. The instruction on mathematics skills and words and stories recommended for the control children by their classroom teachers should have trans-

Table 2
Description and Analysis of Scores on SESAT Mathematic Subscale

	Fall		Spring	
	M	*SD*	*M*	*SD*
Experimental				
Kindergarten	6.25	2.06	21.00	2.58
First grade	17.50	4.90	31.50	5.68
Combined	13.75	6.86	28.00	7.01
Control				
Kindergarten	7.50	5.75	19.50	5.75
First grade	16.75	4.20	32.13	3.44
Combined	13.67	6.40	27.92	7.43

	Analysis of Variance			
	df	*MS*	*F*	*p*
Source				
Grade (G)	1	39.59	32.05	<.001
B/N grades	10	1268.76		
Instruction (I)	1	.09	.00	>.05
G×I	1	.01	.00	>.05
W/N G×I	10	19.69		
Time (T)	1	2100.01	200.66	<.001
G×T	1	4.59	.44	>.05
W/N G×T	10	10.47		
I×T	1	1.26	.09	>.05
G×I×T	1	11.34	.85	>.05
W/N G×I×T	10	13.37		

Table 3
Description and Analysis of Scores on MAT Mathematic Concepts Subscale

	Fall		Spring	
	M	*SD*	*M*	*SD*
Experimental				
Kindergarten	7.50	1.73	10.25	1.50
First grade	12.63	2.97	19.13	2.95
Combined	10.92	3.58	16.17	5.02
Control				
Kindergarten	5.75	3.86	12.00	4.32
First grade	10.50	2.62	17.38	4.63
Combined	8.92	3.73	15.58	5.07

	Analysis of Variance			
	df	*MS*	*F*	*p*
Source				
Grade (G)	1	388.01	22.93	<.001
B/N grades	10	16.92		
Instruction (I)	1	10.01	.78	>.05
G×I	1	10.61	.82	>.05
W/N G×I	10	12.87		
Time (T)	1	333.76	33.71	<.001
G×T	1	12.76	1.29	>.05
W/N G×T	10	9.90		
I×T	1	10.01	2.49	>.05
G×I×T	1	6.51	1.62	>.05
W/N G×I×T	10	4.02		

ferred more directly to the posttests. That the experimental children made equal academic gains is encouraging, because they also had the cognitive benefits of the instruction on concrete operations.

Two factors may have limited the effects of the instruction on concrete operations. First, most of the children were first graders, who had already made good progress in the concrete operations taught. Second, half the students were immigrants for whom English was a new language. Their relatively poor classroom performance might therefore not reflect a cognitive deficit so much as a language deficit. In fact, the children needed no seriation instruction and only limited classification instruction, in contrast to the children studied by Pasnak (1987) and Pasnak et al. (1991). These differences in the children receiving the instruction probably account for the differences in its effectiveness. The major importance of the present research may be that it indicates some limitations in populations for which this type of instruction may be useful.

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