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ABSTRACT

The effect of programmed tutoring on mathematics achievement for kindergarten and first grade children was investigated. The program used discovery-based activities, with each child working on a one-to-one basis with an adult aide. The adult tutor received about 30 hours of training in the program but no direct instruction in mathematics or classroom teaching methods. Significant differences were found in concepts and computational skills when the "Programed Math Tutorial" was used as a supplement to regular instruction. A listing of the eleven major content topics in the program is included. (LS)

THE EFFECT ON MATHEMATICS ACHIEVEMENT OF PROGRAMED TUTORING AS A METHOD OF INDIVIDUALIZED, ONE-TO-ONE INSTRUCTION

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The process of developing a set of programed tutoring strategies and content materials for a year-long program of instruction usually requires several revision-evaluation cycles. The 1972-73 school year was the third cycle in the development of the first grade Programed Math Tutorial (PMT). One purpose of the field studies conducted during 1972-73 was to evaluate, with large numbers of children, the most recent revision of the programed tutoring strategies and content materials for first grade mathematics.

During an earlier field study, it was determined that about 100 lessons of the first grade PMT were suitable for kindergarten children. The kindergarten PMT was in the first cycle of development and it seemed important to determine whether or not kindergarten children could learn first grade mathematics if it were taught by programed tutoring. The second purpose of the field studies, then, was to evaluate the effectiveness of the first grade PMT with kindergarten children.

The PMT and Programed Tutoring

Programed tutoring was developed first as a method for teaching beginning reading. It has proved to be effective, particularly for children who have difficulty learning in the regular classroom situation. Results have indicated that the effectiveness of the method is due to the tutoring strategies and not just to one-to-one instruction or additional instruction time. In the study reported by Ellson and others in 1968, three treatment groups were employed--programed tutoring, directed tutoring and an untutored control group. The first two groups received tutoring as a supplement to regular classroom instruction while the untutored control group received only the regular classroom instruction. Directed tutoring is a form of one-to-one instruction in which current classroom methods are adapted to the tutoring situation. These are methods that a good classroom teacher would employ if she had time to give individualized, one-to-one instruction. Adaptations for directed tutoring in the 1968 study were made by subject matter specialists for use by paraprofessionals. The 1968 study pertained to beginning reading; a comparable study of first grade mathematics instruction was conducted during 1970-71 (Ronshausen, 1971). The results of both studies supported the conclusion that neither one-to-one instruction nor additional instruction time is sufficient to increase achievement--increased achievement is dependent upon the tutoring strategies employed.

The child's learning activities are discovery-based. He is rarely given any answers. He is helped to find acceptable answers through brightening--a process in which assistance is given only in gradually increasing degrees of helpfulness and only until the child responds acceptably. The child manipulates toys and other physical models, he participates in games and he frequently responds in ways which do not require oral or written responses. He learns mathematics by <u>doing</u> mathematics. No time is spent on memorization lessons, drills or lessons about mathematics. The child receives 100% positive reinforcement--every acceptable response is rewarded with verbal praise. Negative reinforcement is forbidden; if the child's response is not acceptable, the tutor simply begins the brightening process.

The child's progress in the PMT is individualized in three ways. First, he works at his own rate--there is no specific number of items or lessons he must complete in a tutoring session. Second, within a set of lessons, the lessons on content he has mastered are omitted by the use of keyed criterion lessons. Third, within a lesson, items he has mastered are omitted by the record-keeping procedures. When the child achieves 100% correct responses on a lesson, he proceeds to the next lesson indicated by the keyed criterion lesson.

The tutor, who works with each child 15 minutes daily on a one-to-one basis, is usually a paid or volunteer adult aide. Each tutor receives about 30 hours of training in the PMT during the school year. No instruction in mathematics or classroom teaching methods is given. The tutor learns to use the tutoring strategies and the record-keeping procedures which insure individualization. The tutor should be considered a well-trained technician rather than a partly-qualified teacher.

The content materials and tutoring strategies used by the tutor are highly structured. Two sets of programs are needed and the tutor is expected to follow them word-for-word. The operational programs describe the tutoring strategies--what to say and do whether the child's response is acceptable or unacceptable. The content programs describe the mathematics tasks and the sequence in which they are to be presented to the child. There are 11 major mathematics topics represented in the content programs:

1. sets and subsets;
2. union of sets;
3. one-to-one matching and set relations;
4. cardinal numbers;
5. addition of cardinal numbers;
6. subtraction of cardinal numbers;
7. numeration and place value;
8. equality and number sentences;
9. basic principles of addition;
10. telling time on the hour and half-hour;
11. values of sets of coins.

Lessons on these topics are arranged in a spiral pattern. No attempt was made to adopt the development or sequencing of any of the commonly-used commercial texts but the scope and sequence of the content programs is similar to many others.

The Problem

In order to implement the field studies reported here, six assumptions were made, based on 11 earlier studies of programed tutoring as an instructional method for reading and mathematics.

1. Programed tutoring should be used as a supplement to the classroom mathematics instruction.
2. One session daily is about as effective as two sessions daily; due to the cost, only one daily session is given.

3. The optimum length of the tutoring session is 15 minutes.
4. Replacement of a tutor during the school year has no effect on the children's achievement (there is rarely more than one replacement of a tutor during the year in most schools).
5. Every success is rewarded (100% positive reinforcement).
6. The effectiveness of programed tutoring is due to the tutoring strategies rather than one-to-one instruction or additional instruction time.

The field studies were undertaken to seek answers to the following questions.

1. Is the revised Programed Math Tutorial used as a supplement to the regular classroom instruction more effective than classroom instruction alone in helping first-graders learn mathematics?
2. Is the revised Programed Math Tutorial used as a supplement to the regular classroom instruction more effective than classroom instruction alone in helping kindergarten children learn first grade mathematics?

"Effectiveness in helping children learn" was to be measured in terms of scores on standardized and criterion referenced mathematics achievement tests.

Method

The Programed Math Tutorial was field-tested in two large school systems during the 1972-73 school year. School System A serves a large midwestern city with a distinct inner-city area; there are 58,000 children in grades K-6. School System B serves a large West Coast city in which several minority groups reside. There is no distinct inner-city area. About 28,000 children attend grades K-6.

In these two systems, three essentially separate field studies of the first grade PMT were conducted. The same experimental design was used in each. Details of selection procedures, the pretest and posttest measures employed and length of the field trial varied according to local needs. After children were selected, they were assigned to the tutoring group or to the untutored control group. Children in the experimental group were tutored one-to-one 15 minutes daily, using the PMT as a supplement to regular classroom instruction. Children in the untutored control group received only the regular classroom instruction. After several months of tutoring, children in both groups were given the posttest achievement measures. Scores on the tests and subtest were analyzed by appropriate statistical procedures.

School System A

In September, 1972, first grade children who had been selected earlier to receive reading tutoring in the seven participating schools were given the Metropolitan Readiness Tests. Using total scores, a stratified random sample was formed in each school. Children were assigned alternately to the tutored group or to the untutored control group, beginning with the lowest score. Tutors were assigned randomly to the schools after the number of children selected for tutoring was known. Shortly after tutoring began, two schools were dropped to meet Title I requirements. Three new schools were added and the selection procedure was carried out in those schools. Children in the latter group participated for five months while the children selected earlier participated for nearly eight months. Because of the selection procedure employed, all children participating in the field test were receiving reading tutoring. In May, children in the experimental and control groups were given the mathematics subtests (4A-Concepts and 4B-Computational Skills) of the Metropolitan Achievement Tests, Primary I.

Because earlier studies of programed tutoring showed treatment-readiness level interaction, a two-factor ANOVA design for analysis of post-test scores was preferred. The difference in mean pretest scores, favoring the control group, as reported in Table 1, is statistically significant, so a one-factor fixed effects analysis of covariance design was employed instead. The pretest score was used as the covariate. Scores on each subtest as well as scores on the combined subtests were analyzed in this design. Data from the combined subtests are summarized in Table 2, data from the concepts subtest are summarized in Table 3 and data from the computational skills subtest are summarized in Table 4.

School System B

The Programed Math Tutorial was used with both kindergarten and first grade children so that two essentially separate field studies were completed in this school system. At the kindergarten level, 36 children were selected randomly from all readiness levels, 18 in each of two schools. The control group was formed in the same way from the same classrooms. The Numbers subtest of the Metropolitan Readiness Tests was used as the pretest. The difference in mean pretest scores favors the untutored control group but it is not statistically significant (Table 1).

Scores on the Numbers subtest of the Metropolitan Readiness Tests were used to rank children in the first grade classes in 14 schools. Each school hired the number of tutors it could provide, producing s tutoring time slots. Then, in each school, the 3/2 s lowest pretest scores were selected. The children thus selected were assigned randomly to the tutored or untutored control groups in the ratio of about three to two. There was no difference in mean pretest scores between the experimental and control groups (Table 1).

After eight months of tutoring, children in the experimental and control groups at each grade level were given two posttest achievement measures. Kindergarten children were given the mathematics subtests of the Metropolitan Achievement Tests, Primer and the Primary School Mathematics Criterion Test. The latter measure was given to the first-graders, also, along with the mathematics subtests of the Metropolitan Achievement Tests, Primary I.

The Primary School Mathematics Criterion Test (PSMCT) contains 52 items (37 for concepts and 15 for computational skills) which measure achievement of instructional objectives common to many first grade texts and to the Programed Math Tutorial. At the first grade level, the coefficient of correlation of the PSMCT with the mathematics subtests (4A + 4B) of the Metropolitan, Primary I, is .80. At the kindergarten level, the coefficient of correlation of the PSMCT with the mathematics subtests of the Metropolitan, Primer, is .85. While reliability coefficients are not usually reported for a criterion referenced measure, this information is requested by some researchers. The coefficient of reliability, computed using an odd-even split-half procedure and corrected by the Spearman-Brown formula, is .94 using kindergarten ata and .90 using first grade data.

Scores on each test and subtest were analyzed by means of a two-tailed _t_-test. Data from the concepts subtest of each measure are summarized in Table 3, data from the computational skills subtests are summarized in Table 4 and data from the combined subtests are summarized in Table 2.

Results

The data from analyses of scores on the combined mathematics subtests are summarized in Table 2. In each school system, the mean score obtained by the tutored group exceeded the mean score obtained by the untutored control group and the differences are statistically significant in five of six cases ($p<.001$, $p<.10$). This result occurred at the kindergarten level as well as the first grade level in School System B ($p<.001$). The mean score obtained by the tutored kindergarten group is essentially the same as that obtained by the untutored control group for first grade on the PSMCT (34.5 vs 34.7). The difference in mean pretest scores, however, favors the first grade untutored control group and is significant beyond the .05 level.

The mathematics subtests of the _Metropolitan Achievement Tests_, Primary I, contain many items which test objectives not included in the _Programed Math Tutorial_. The _Criterion Items Subtest_ (CIS) was prepared by deleting irrelevant items from Subtests 4A and 4B of the _Metropolitan_, forming a criterion-referenced measure. This measure was used only in School System A. The Cronbach Alpha, a measure of internal consistency, is .77.* The Cronbach Alpha for the combined subtests 4A and 4B of the Metropolitan (from which the CIS was prepared) is .89.

Both school systems reported scores for each subtest separately. Data from analyses of concepts subtests are summarized in Table 3 and data from analyses of computational skills subtests are summarized in Table 4. In each school system, for each subtest, the mean score obtained by the tutored group exceeded that obtained by the untutored control group. The differences in mean scores on the concepts subtests were statistically signigicant ($p < .001$ to $p < .05$). The differences in mean scores on the computational skills subtests were statistically significant only in School System B ($p < .001$, $p < .01$).

Data obtained in School System A were analyzed by readiness levels, also. No significant differences or interactions were found, so the data are not reported here.

Data concerning tutor characteristics and numbers of tutoring sessions were made available by both school systems. Only paid adult aides participated in the field studies. The "average" tutor in School System A was female, aged 42, with about 5 years' programed tutoring experience and 12 years' formal education. All had previous experience with young children outside the home and school. In School System B, the "average" tutor was female, aged 37, 1-1/2 years' programed tutoring experience and 13 years' formal education. Additional descriptive data are summarized in Table 5.

* Since the items were scored right-wrong, the Cronbach Alpha is equivalent to the coefficient which would be obtained from the Kuder-Richardson 20 formula.

The maximum number of tutoring sessions possible in each school system was 140. Because of absences and interference with other school activities, the average kindergarten child (School System B only) completed 103 sessions (range of 84-116) or about 25-3/4 hours of tutoring. The average first-grader in School System B completed 104 sessions, or 26 hours of tutoring (range of 84-119 sessions). In five of the participating schools in School System A, the average child completed 97 sessions, or 24-1/4 hours of tutoring (range of 62-121 sessions). The average child in the other three participating schools in that system completed 76 sessions, or 19 hours (range 45-89 sessions). Since the Programed Math Tutorial is always provided as a supplement to the regular classroom instruction, the hours of programed tutoring represent additional instruction time in mathematics.

Conclusion and Discussion

The data in Table 2 support the conclusion that the Programed Math Tutorial used as a supplement to regular first grade instruction is more effective than classroom instruction alone in increasing first-graders' mathematics achievement.

From the data summarized in Table 2, it seems that kindergarten children can learn first grade mathematics topics when the Programed Math Tutorial is provided as a supplement to the regular classroom instruction. Further, one year of programed tutoring as a supplement to the regular kindergarten instruction is equivalent (in terms of achievement test scores) to one year of regular classroom instruction for first-graders, nearly all of whom were in kindergarten the previous year. The PMT was effective in helping the kindergarten children learn mathematics concepts (Table 3) and it seemed to be particularly effective in helping the kindergarten children learn computational skills. The mean score in computational skills obtained by the kindergarten tutored group is twice that of the untutored control group (Table 4).

The use of the PMT as a supplement to regular classroom instruction seems to be more effective than regular classroom instruction alone in helping the children learn mathematics concepts (Table 3). The combination is not particularly more effective in helping first-graders learn computational skills. The lack of significant differences between the mean scores of the tutored and untutored control groups may indicate that classroom teachers devote more time to teaching first-graders computational skills than mathematics concepts, or that their instruction is more effective for computational skills than for mathematics concepts. Another possibility pertains to the design of the PMT--mathematics concepts are emphasized throughout. Computational skills are not neglected, though, and the findings in the kindergarten field study seem to suggest that the lack of a significant difference in computational skills mean scores for first-graders is not due to the design of the PMT.

Recommendations for Future Research

The kindergarten field study should be repeated. The experimental and control groups were small (32 and 33, respectively). There were only two schools in one school system and these schools were neither typical of the entire school system nor typical of the schools in which programed tutoring seems to provide the greatest benefits (inner-city or rural).

Since this field study ended, the kindergarten PMT has been completed. A study is needed in which the kindergarten PMT and the first grade PMT are used with kindergarten children to determine which is more effective after one year of tutoring. Longer-lasting effects of each level of PMT might be measured one and/or two years later.

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TABLE 1

Summary of Pretest Mean Scores, Values of t and Levels of Significance

			Treatments						
School System	Grade	Pretest Measure	Tutored	N	Untutored Control	N	Diff. in Means	t	p
A	1	Metropolitan Readiness Tests	37.9	140	43.1	85	-5.2	-3.18*	<.01
B	1	Metropolitan Readiness Tests, Numbers Subtest (#5)	11.7	136	11.7	78	0	0	NS
B	K	Metropolitan Readiness Tests, Numbers Subtest (#5)	9.9	32	10.7	33	-0.8	- .72	NS

* t was calculated as $\sqrt{F}$

TABLE 2

Summary of Posttest Mean Scores for Treatments, Values of *t* and Levels of Significance--Combined Mathematics Subtests

School System	Grade	Posttest Measure	Treatments: Tutored	N	Treatments: Untutored Control	N	Diff. in Means	t	p
A	1	Metropolitan Achievement Tests, Primary I, 4A + 4B	27.2 (28.1)**	140	27.7 (26.2)	85	1.9	1.72*	<.10
A	1	Criterion Items Subtest, Concepts + Computational Skills	10.4 (10.7)	140	10.5 (10.0)	85	.7	1.80*	<.10
B	1	Metropolitan Achievement Tests, Primary I, 4A + 4B	34.7	136	33.0	78	1.7	1.21	NS
B	1	Primary School Mathematics Criterion Test	39.1	136	34.7	78	4.4	4.28	<.001
B	K	Metropolitan Achievement Tests, Primer, Math Subtests	26.1	32	19.7	33	6.4	4.16	<.001
B	K	Primary School Mathematics Criterion Test	34.5	32	23.0	33	11.5	5.81	<.001

* t was calculated as $\sqrt{F}$

** adjusted mean scores obtained in ANCOVA are shown in parentheses; the pretest total score was the covariate.

TABLE 3

Summary of Posttest Mean Scores for Treatments, Values of *t* and Levels of Significance--Mathematics Concepts

School System	Grade	Subtest	Treatments: Tutored	N	Treatments: Untutored Control	N	Diff. in Means	t	p
A	1	Metropolitan Achievement Test, Primary I, Subtest 4A	17.2 (17.7)**	140	16.7 (15.9)	85	1.8	2.97*	$<.01$
A	1	Criterion Items Subtest, Concepts Section	6.1 (6.3)	140	6.0 (5.7)	85	.6	2.55*	$<.02$
B	1	Metropolitan Achievement Tests, Primary I, Subtest 4A	21.3	136	19.8	78	1.5	2.03	$<.05$
B	1	Primary School Mathematics Criterion Test, Concepts Section	28.6	136	25.3	78	3.3	4.86	$<.001$
B	K	Metropolitan Achievement Tests, Primer, Concepts Section	16.3	32	14.7	33	1.6	2.38	$<.01$
B	K	Primary School Mathematics Criterion Test, Concepts Section	26.9	32	19.3	33	7.6	5.44	$<.001$

* t was calculated as $\sqrt{F}$

** adjusted mean scores obtained in ANCOVA are shown in parentheses; pretest total score was the covariate.

TABLE 4

Summary of Posttest Mean Scores for Treatments, Values of t and Levels of Significance--Mathematics Computational Skills

School System	Grade	Subtest	Treatments: Tutored	N	Treatments: Untutored Control	N	Diff. in Means	t	p
A	1	Metropolitan Achievement Tests	9.8 (10.2)**	140	10.8 (10.1)	85	.1	.80*	NS
A	1	Criterion Items Subtest, Computational Skills Section	4.3 (4.4)	140	4.5 (4.2)	85	.2	.74*	NS
B	1	Metropolitan Achievement Tests	13.4	136	13.1	78	.3	.36	NS
B	1	Primary School Mathematics Criterion Test, Computational Skills Section	10.5	136	9.3	78	1.2	2.75	$<.01$
B	K	Metropolitan Achievement Tests, Primer, Computational Skills Section	9.7	32	4.9	33	4.8	3.81	$<.001$
B	K	Primary School Mathematics Criterion Test, Computational Skills Section	7.6	32	3.8	33	3.8	4.49	$<.001$

* t was calculated as $\sqrt{F}$

** adjusted mean scores obtained in ANCOVA are shown in parentheses; pretest total score was the covariate.

TABLE 5

Tutor Characteristics*

	School System A		School System B	
	mean	range	mean	range
Age (years)	42	20-62	37	19-55
Formal Education (years)	12	11-19	13	10-16
Programed Tutoring Experience (years)	5	1-9	1-1/2	1-3
Percent Having Experience with Children Outside Home and School	100%		76%	
Percent Having Non-tutoring School Experience	7%		25%	
	N = 14		N = 33	

* All tutors were female.