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EFFECTIVENESS OF AUTOMATED VISUAL PROGRAMED INSTRUCTION WITH PARAPLEGIC AND OTHER SEVERELY HANDICAPPED STUDENTS.

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DESCRIPTORS- *PHYSICALLY HANDICAPPED, *PROGRAMED INSTRUCTION, *ARITHMETIC, *TEACHING MACHINES, *INDIVIDUAL INSTRUCTION, VISUAL LEARNING, SECONDARY SCHOOL STUDENTS, DOWNEY, CALIFORNIA, RANCHO LOS AMIGOS HOSPITAL

TWENTY-EIGHT PARAPLEGIC, QUADRUPLEGIC, CEREBRAL PALSIED, AND OTHER SEVERELY PHYSICALLY HANDICAPPED SECONDARY STUDENTS, PATIENTS IN THE LOS ANGELES COUNTY RANCHO LOS AMIGOS HOSPITAL, WERE INCLUDED IN A STUDY OF THE EFFECTIVENESS OF AUTOMATED VISUAL PROGRAMED INSTRUCTION. SUBJECTS WERE DIVIDED INTO FOUR MATCHED GROUPS BY READING LEVEL AND INTELLIGENCE. FOUR TREATMENT MODES WERE USED TO TEACH ARITHMETIC FRACTIONS AND DECIMALS. TWO GROUPS ALTERNATED BETWEEN TEACHING MACHINES (TM) AND CLASSROOM (C). ONE GROUP REMAINED CONTINUOUSLY WITH THE TEACHER AND ONE CONTINUOUSLY WITH THE MACHINES. MACHINE CONTROLS WERE ADAPTED TO DISABILITIES. INDEPENDENT VARIABLES WERE--(1) INSTRUCTION MATERIALS WITH UNITS SPLIT AT MIDPOINT PROVIDING FOUR UNITS--INSTRUCTIONAL CONTENT USED BY MACHINES AND TEACHERS WAS IDENTICAL, (2) MODES OF INSTRUCTION, AND (3) MATCHING CRITERIA, READING LEVEL AND INTELLIGENCE. DEPENDENT VARIABLES WERE--(1) TIME REQUIRED TO COMPLETE UNITS, (2) PERFORMANCE IN TERMS OF MEAN DIFFERENCE SCORES (PRETEST, MIDTEST, POST-TEST), AND (3) RATE OF LEARNING AND PERCENT OF ERROR. FINDINGS WERE--(1) THE TM MODE OF INSTRUCTION WAS ABOUT TWO-THIRDS MORE EFFICIENT IN TIME, (2) THE TM MODE WAS MOST EFFECTIVE IN TANDEM WITH THE C MODE, (3) THE TM MODE WAS MOST EFFECTIVE WITH LOWER INTELLIGENCE SUBJECTS, (4) THE C INSTRUCTION MODE BECAME MORE EFFECTIVE AS INSTRUCTION MATERIAL BECAME MORE COMPLEX (DIFFICULT), (5) THE MOST EFFECTIVE SEQUENCE IS TM FOLLOWED BY C INSTRUCTION, AND (6) OPERATION OF MACHINES CAN BE ADAPTED TO DISABILITIES. (TC)

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FINAL REPORT
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December 1966

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

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Joe Glenn Coss
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Leonard V. Wendland
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December 1966

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Downey Unified School District
Downey, California

The Assurance of Compliance with Title VI of the Civil Rights Act of 1964, dated January 18, 1965, applies to the report submitted herewith.

(Signed) Bruce Moore

Bruce Moore, Superintendent
Downey Unified School District
Downey, California

Jan 4, 1967
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Introduction

The objectives of education for all children are usually modified to fit individual needs. Educators working with severely handicapped children in a hospital are cognizant of the special needs of this population and attempt to meet them. Difficulties arise, however, because of institutional, administrative, and instructional limitations.

Hospitals are designed primarily for medical reasons — surgery, treatment, and convalescence. Educational programs for patient-students are therefore commonly confined to the convalescent period, but even this is frequently interrupted for therapy. Although the amount of time available for education is considerably less than that for the non-handicapped, students of this population are generally expected to meet the same requirements for graduation.

The severity of the physical handicap may limit the manipulative ability of the learner. The inability to write or turn the pages of a book are illustrative of the difficulties which affect learning.

The Downey Unified School District is responsible for the education of an average of one hundred hospitalized children who are patients of the Los Angeles County Rancho Los Amigos Hospital. Nearly sixty percent of the patient-students are polio, paraplegic, or quadruplegic; twenty percent are traumatic brain-injured; and twenty percent have other neurological impairments such as muscular dystrophy, arthritis, and cerebral palsy.

Elementary and secondary classes are conducted within the hospital in special rooms for those whose physical condition may require emergent treatment, and in a nearby district school for those with sufficient tolerance to be transported by special trams. Bedside instruction in all subjects for one hour per day is also provided.

Teachers are constantly seeking more effective and efficient methods and devices to improve learning for this population. Audio-visual aids have been used with some success for several years. Currently automated instruction is beginning to find a secure place in instructional technology. These new techniques stress individualization of instruction and efficiency of presentation in the learning process.

Research has supported the use of automated instruction with non-handicapped both in terms of effectiveness and efficiency where the subject material was logical and sequential. Lumsdaine and Glaser,(1) and Hughes and McNamara (5) have reported studies showing the effect of automated instruction in the learning situation, and Goldberg and Dawson (4) reported on the efficiency of programed texts and teaching machines. Some investigators have reported on the effectiveness of automated instruction with mentally retarded children. Blackman and Copobianco,(3) Malpass, Hardy, Gilmore, and Williams.(6) Would it be effective with the severely physically handicapped?

Teaching machines have some desirable characteristics:

1. They can accommodate a variety of instructional materials with differing degrees of difficulty.

2. They can present this material on demand of the students and according to their abilities to cope with it.

3. They permit students to proceed at their own rates without external pressure.

4. If progress is interrupted for a period of time due to surgery or illness, they may, upon return, review or resume their learning experiences at the points of interruption.

5. They can provide instruction materials prepared by experts in each field of learning.

6. Because they are under command and control of the students, and can provide immediate reinforcement, they appear to generate some motivation for learning.

Teaching machines of branching, modified linear, or looping sequence have some additional characteristics:

1. They can provide corrective lessons, illustrations, exercises, and reviews.

2. They can allow students to repeat any concept or sequence if not understood.

In order to determine the effectiveness of automated instruction with the severely physically handicapped population in the hospital school, the research group chose arithmetic as the subject vehicle. It is a subject which is logical, cumulative in content, and sequential.

A search was conducted to select a teaching machine which would provide a branching or looping sequence and which could accommodate an arithmetic program. A variety of machines were examined. The Autotutor, at that time a product of United States Industries, Inc., seemed to combine the characteristics required. Furthermore, it had a sequential arithmetic program completed and available. The course consisted of four reels of 35mm film dealing with whole numbers, and one each dealing with fractions, decimals, percentage, and ratio and proportion. (See appendix A)

Selection of Teaching Machine. A demonstration Autotutor and program were obtained and evaluated by the research staff. Some of the control considerations which had to be resolved before the Autotutor was adopted included:

1. Could its panel of controls be modified so that quadruplegics could operate it?

2. Could it be positioned and operated in such manner that the program could be seen from various angles?

The orthotics specialists at the Rancho Los Amigos Hospital examined the equipment and satisfied themselves that the control mechanism could be modified, and that it would operate in various positions. (See appendix B)

The project was concerned with the evaluation of one automated instruction method in teaching a rational and sequential subject matter (arithmetic) to a sample of severely physically handicapped students. The general question was asked: What is the nature of the relationship between intellectual ability and the possible differential effectiveness of automated instruction and classroom instruction? Would this relationship be different with a non-handicapped population?

Method

Handicapped Subjects. Twenty-eight inpatients at the hospital were included in the study. The ages of the subjects ranged from 12-21 years with an average of 16.66 years. Subjects had a mean IQ of 97.50 (Wechsler Adult Intelligence Scale or Wechsler Intelligence Scale for Children). The sample consisted of 9 postpolio, (5 quadruplegic, 4 paraplegic), 1 quadruplegic, 1 paraplegic, 1 amyotonia congenital, 3 arthritic, 5 muscular dystrophy, 3 hemiparetic, 1 cerebral palsy, 1 frontal lobe trauma, 2 Gullian-Barre, and 1 spina bifida. The average length of disability for the sample was 8.58 years.

As indicated by performance on the STEP 3A Reading Test, (The Sequential Test of Educational Progress), the mean reading level for the sample was 271.00 in terms of converted score. This is comparable to the reading level of the eighth-grade sample presented in the publisher's norms (viz., 268.00).

The subjects ranged in grade placement from seventh through the twelfth grade with a mean of the tenth grade. While the experimental Ss performed at the eighth grade level with respect to reading, they had an average grade placement of the tenth grade. Thus, in terms of reading ability, a two-year lag is evident when comparing the hospital students with national norms.

A seventh grade reading ability was recommended for successful completion of the programed instruction by the authors of the program. Therefore, a cutoff point for screening subjects on the STEP Reading Test was established at the third quartile of the seventh grade national norms.

Non-handicapped Students. Forty-eight handicapped students had originally been qualified for the study by STEP reading and WISC or WAIS intelligence scores prior to beginning the experiment. Forty-eight non-handicapped were matched to the handicapped as nearly as possible on STEP form 3B, reading; SCAT form 4A, (School and College Ability Test), for grade 8 students; and CTMM, (California Test of Mental Maturity), levels 2 and 3, long form, for grades 7 and 9. (Discharges reduced the handicapped to 28, and 47 completed the non-handicapped phase.)

Non-handicapped Ss had the following grade placement: 19

seventh grade, 17 eighth grade, and 11 ninth grade. The mean STEP reading level was 264.19. The mean intelligence level was 96.00. (The SCAT yielded lower scores than the CTMM in all instances where both scores were found for the same subjects.)

Design. Subjects were divided into four groups which were matched in terms of reading level and intellectual ability. A description of the four treatment modes follows:

1. The first group, N=7, received the teaching machine (TM) mode of instruction over the first half of the unit and the classroom (C) mode of instruction over the second half of the unit. This group is symbolized as TM→ C.

2. A second group, N=7, received a counterbalanced order, i.e., classroom instruction over the first half of unit and teaching machine over the second half of unit. This group is symbolized as C→ TM.

To assess any possible effects that might have resulted from making the transition from one mode of instruction to another (e.g., novelty) and to allow for the evaluation of the longitudinal effects of each of the teaching modes, two "continuous" groups were established.

3. The third group, N=8, received the teaching machine mode of instruction across both halves of the instruction units (viz., TM→ TM).

4. The fourth group, N=6, received the classroom mode of instruction across all subject material (viz., C→ C).

Within each group, Ss were divided at the median into high and low intelligence groups. A recapitulation of the experimental design is presented in Table I.

Independent Variables.

1. Instructional material: Units covering fractions and decimals were split at the mid-points, thus, making four units of instruction.

2. Teaching machine mode of instruction.

3. Classroom mode of instruction: Teachers used texts prepared

TABLE 1

EXPERIMENTAL DESIGN SUMMARY

	Unit of Instruction			
	1st half fractions	2nd half fractions	1st half decimals	2nd half decimals
I. Machine 1st half Classroom 2nd half (TM→ C)	TM	C	TM	C
II. Class 1st half Machine 2nd half (C→ TM)	C	TM	C	TM
III. Class Continuous (C→ C)	C	C	C	C
IV. TM Continuous (TM→ TM)	TM	TM	TM	TM

Note: Cell entries of table represent instructional modality received over that half unit of instruction.

from the material covered by the TM.

4. Matching criteria: STEP 3A Reading Test, and WAIS or WISC.

<u>Dependent Variables.</u>

1. Amount of instruction time required to complete units (TM vs C).

2. Performance on the arithmetic achievement tests (Career Arithmetic Series: Fractions and Decimals Surveys) in terms of mean difference scores (i.e., pretest, midtest, posttest).

3. Rate of learning material presented on TM (% errors/frames/minute). Since the rate with which the S progressed through the program was partially dependent upon the correctness of responses, this derived measure took into account the percentage of error made over any unit of material.

The design made possible consideration of the following:

1. What is the relationship between complexity of subject matter (i.e., increasing difficulty of solution) and the effectiveness of the two teaching modes?

2. When the two teaching modes are combined in some sequence (i.e., automated preceeding classroom instruction, or classroom preceeding automated instruction), is the sequence of instruction related to changes in performance?

3. What is the relationship between the intellectual level of the students and performance under each sequence of instruction?

4. What is the relationship between economy of instructional time and teaching mode?

5. What is the relationship between performance and the change to a new teaching mode?

The design of the project called for groups of non-handicapped students who would be matched as nearly as possible with the severely physically handicapped students in the hospital. This phase of the study was carried out in a nearby junior high school. The conditions under which it was conducted made comparison with the hospital study impossible. The text material extracted from the Autotutor film was traditional arithmetic. The State texts contain the new mathematics, and while the content is similar the emphasis and approach are not. The instruction which the students received from the teaching machine was not the same as that given in the classroom. (See appendix. C)

Apparatus. Teachers' texts were prepared from the material presented on the Autotutor film in order to equate instructional materials presented by the teaching machines and the classroom. The four programs concerned with Fractions, Decimals, Percentage, and Ratio and Proportion were copied. The material was mimeographed and bound into volumes for teacher use as a guide and manual. The handicapped used only the programs dealing with Fractions and Decimals. (See appendix D)

The tests at the end of each programed lesson were reproduced so that each student in the classroom situation would be tested on the same material as presented on the machine.

Teaching Machine. Operation of the machine and the learning sequence are described by the Autotutor Operator's Handbook as follows:

> "The student reads a frame of instructional material as projected onto the viewing screen. At the bottom of the frame he finds a multiple choice question with letters "A" through "I" used to identify each possible answer. The student decides which of the possible answers is correct and presses the lettered Response Buttom corresponding to his answer choice. Pressing the selected Response Button starts the machine into its automatic cycle quickly to find and project the frame corresponding to that answer choice. If the answer was correct, the new frame will advise that it was correct, generally state why it was correct, and then proceed with additional instructional text, ending in another multiple choice question to which the student will respond as before.
>
> "If the student's answer choice was incorrect, the frame corresponding to that incorrect button response

will advise that the selected answer was wrong, explain why it was wrong and offer additional explanatory information so that the student will have continued learning, even from the wrong answer. At the bottom of each typical wrong answer frame, the student is directed to press the "R" button which, through the memory system built into the machine, causes the last prior frame (the one where the last question has been asked) to reappear, so that the student can choose again to find the right answer. Not only is the student directed to "Return", but he is restricted from proceeding forward, either accidentally or deliberately, by a special capability of the machine which sends a film-formed code and immobilizes the forward control buttons."

An error-counter attachment on the teaching machine recorded the number of errors made by the S (i.e., the number of times the "Return" button had been used).

Modification of Machine. In modifying the machines for the patient-students, it was essential that the operational characteristics be retained. The basic problem confronting the Experimenter was to provide a control mechanism which could be operated with almost no physical effort. Microswitches were already used to operate prosthetic devices.

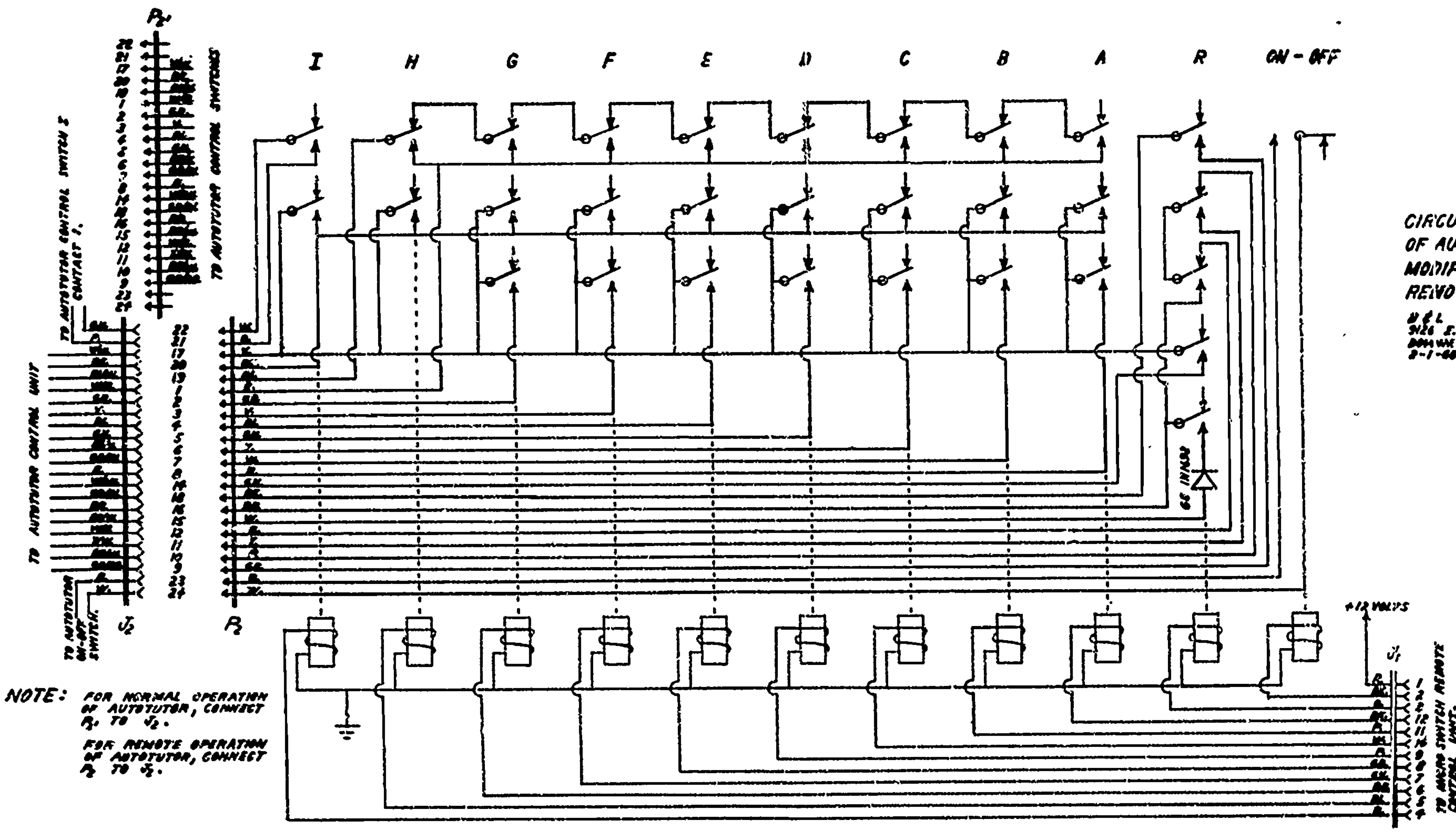
The distributor of the Autotutor, in authorizing mechanical modification of the machines, specified that they must be returned to their original operating condition. In order to comply with this specification, the orthotics department adapted a by-pass which permitted an external electronic relay unit to activate the program. The microswitch controls replaced the button controls on the machine panel. (Schematic diagram.)

The machine was usually positioned on an adjustable table to permit maximum visibility. (Illustration 1) The microswitch control pattern was affixed to the cover above the screen. For those students who were prone, the machine was placed directly below the edge of the gurney and within comfortable focus. (Illustration 2)

An armature, with locking universal joints and a base clamp, brought the switch assembly into position for use. (Illustration 3) The armature was adjusted by the aide to suit each student. Some

CIRCUIT DIAGRAM
OF AUTOTUTOR
MODIFICATION FOR
REMOTE CONTROL

ENGINEERING
E. FIRESTONE BLVD.
DOWNEY, CALIFORNIA



NOTE: FOR NORMAL OPERATION OF AUTOTUTOR, CONNECT P_1 TO J_2.
FOR REMOTE OPERATION OF AUTOTUTOR, CONNECT P_2 TO J_2.

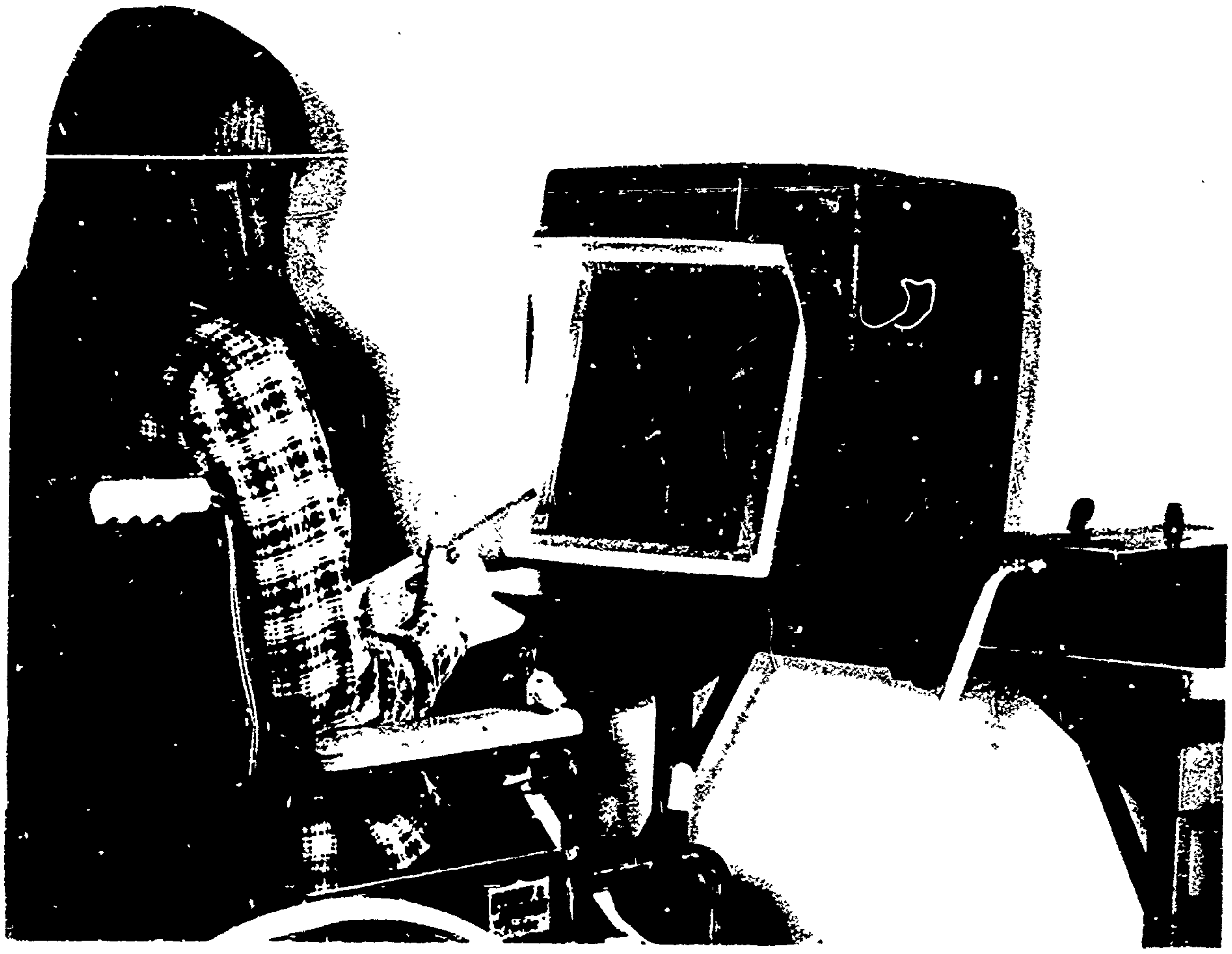


Illustration 1

The Autotutor with the basic modification of outside relay box, microswitch control with clamp, and the microswitch control pattern attached to the lid above the screen.

The student had an acute case of rheumatoid arthritis and could not extend her arms. Prior to the day the picture was taken she had been confined to bed. In the bed situations the Autotutors were placed on their sides on tables adjusted to the eye level of the students, and the microswitch control was placed at the students' convenience.

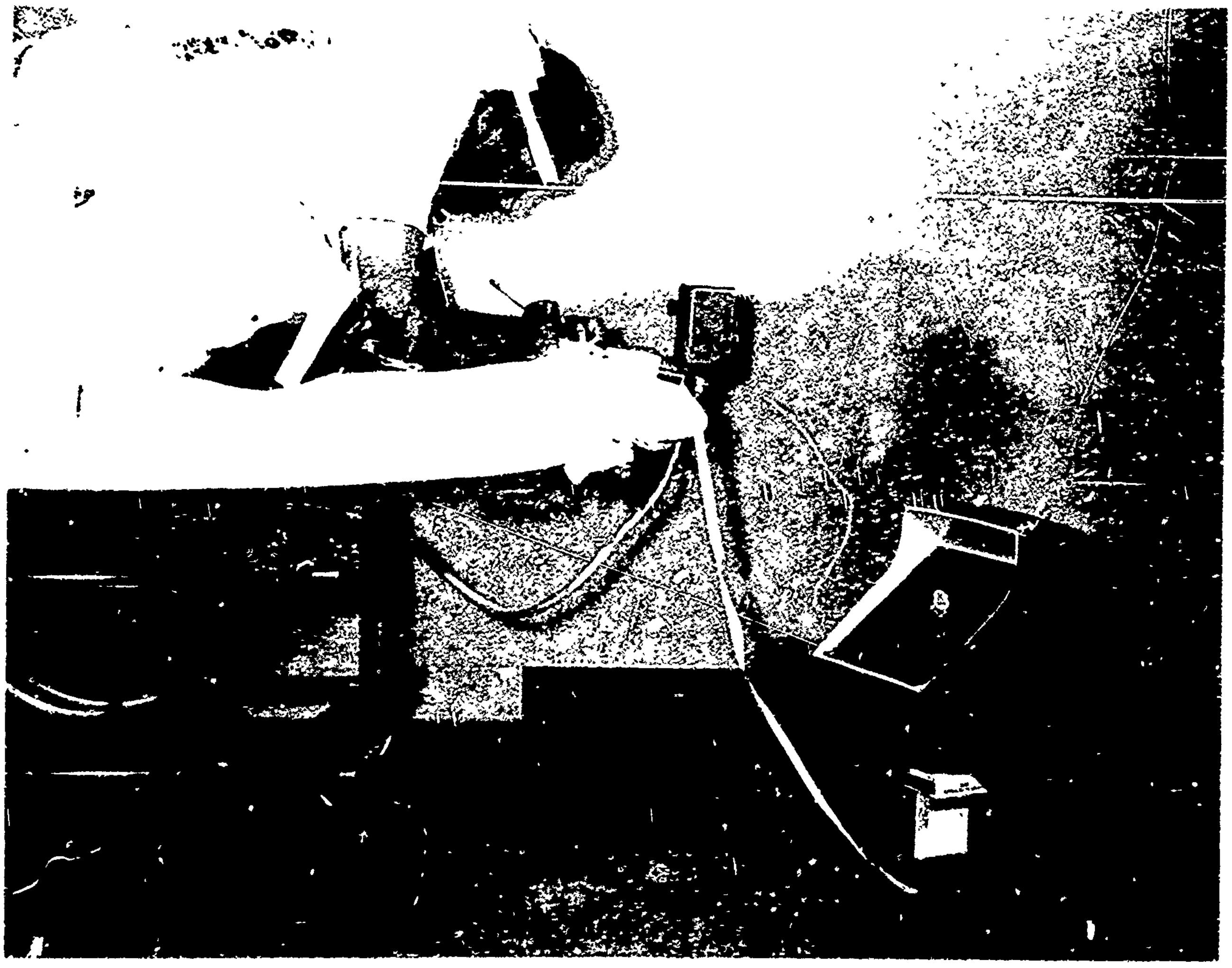


Illustration 2

The student was post-polio and had a spinal fusion. The head was immovable although the arms were functional.

The Autotutor was tilted to bring the screen into the student's direct view. The picture was taken in the hospital studio. In actual practice the student was placed forward so that the head extended beyond the gurney. The machine was placed almost directly below and within easy focus.

Illustration 3

The student was quadruplegic, but had some function of the fingers. The armature to hold the microswitch control was made flexible with universal joints, and could be clamped to the adjustable table or some part of the student's wheel chair.

armatures were also equipped with a mirror so that students using the tongue could see the switch control assembly. (Illustration 4)

Students with paralyzed upper extremities were often more comfortable resting the microswitch control in their laps or on their chests. (Illustration 5) Tongue operation was necessary for two students. Microswitches operate with slight pressure and the students soon determined the correct position for each control. (Illustration 6)

Switch levers were placed as a battery on 3/8" centers. Every other switch was offset to provide two rows. Since operation required an upward motion for one response and downward for another, all students were given a training period to develop mastery of the control system. (Illustration 7)

Isolation Booths. Three-sided wooden booths fabricated from 3/4" x 4' x 4' plywood sheets and painted a flat white were used with each of the machine units. These booths reduced the sources of distraction arising from extraneous visual and auditory stimuli.

Procedure. The Ss who were to receive TM instruction were given preliminary training in the operation of the machine to ensure that during the subsequent instruction phase their performance would not reflect the learning of that operation. For this training phase, a film strip covering English grammar was used. For one week preceding the experimental phase, the Ss were given a daily half-hour training session.

During the experimental portion, the subjects using the teaching machine were given a 25-minute daily session, while the Ss receiving classroom instruction were given the normal 50-minute daily arithmetic session.

While the S received instruction, the Experimenter gave no assistance with regard to the subject material being presented.

Since the programed instruction included some "homework" assignments, it was necessary for the attendant or E to assist those unable to write by transcribing the written portions of the program.

In the classroom, the teacher presented material that was

Illustration 4

The student was quadruplegic. Movement was restricted to the head so tongue operation was necessary. A mirror was attached to the armature for switch identification.

Students adapted to inversion of image, but required training in selection of correct response. Incorrect response was recorded automatically when the R (return) switch was activated, and counted as an error. Progress could not be made without correct response.

Illustration 5

The student was quadruplegic with some function of the fingers and the head. The microswitch control was held in place by the student and operated by the thumb. The switch control was positioned according to the desires or convenience of the student.

Illustration 6

The student was quadruplegic, and had no movement except the head. Disability was such that pointing of the tongue was not possible. Considerable training on the use of the switches was necessary. A lesson series on English was used as the training film.

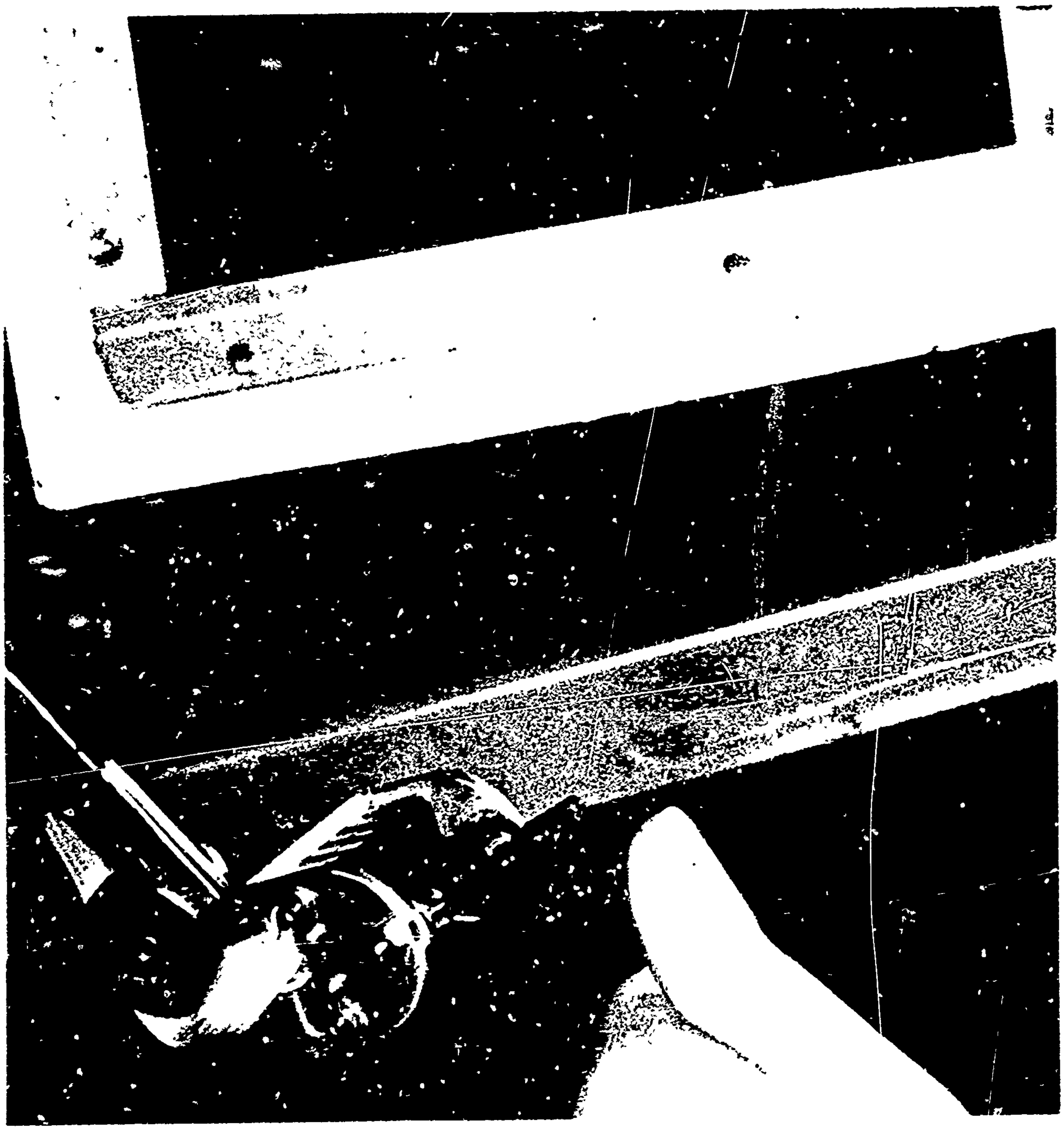


Illustration 7

The microswitch control consisted of six double-contact units. Five switches controlled button selections on the Autotutor. One was used for on--off. Upward contact gave one choice of response, downward gave another. The switches were spring loaded to return to a neutral position upon release. Every other switch was offset. This kept the unit conpact, gave the student a position setting, and provided space for operation.

equivalent to the programed material by using the prepared text.

The experimental procedure can be summarized in the following manner:

a. Pretest on fractions administered.

b. Instruction over first half of fractions unit.

c. Midtest covering fractions administered.

d. Instruction over second half of fractions unit.

e. Posttest covering fractions administered.

f. The same procedure was repeated during the unit on decimals.

Results

Table 2 presents the mean IQ, and the mean reading scores for each of the treatment groups. Relative to these matching criteria, it will be noted that the treatment groups are comparable. None of the differences presented in Table 2 were found to be statistically significant.

TABLE 2

SUMMARY TABLE
MATCHING CRITERIA

	Treatment Groups			
Criteria	TM→ C	C→ TM	TM→ TM	C→C
Mean IQ	91.67	97.50	99.89	94.71
Mean Reading*	258.20	271.00	271.55	260.00
N	7	7	8	6

*Reading Scores are cited in terms of STEP converted score.

The two criterion measures employed for the experimental analysis were the mean difference scores between performance on the pretest and midtest and between performance on the midtest and posttest.

Three factors were taken into account in the analysis of variance: (1) Sequence of instruction methods (TM→ C, C→ TM, C→ C, TM→ TM; (2) Units of instruction (Fractions and Decimals); and (3) Intelligence (high and low). Table 3 contains the appropriate mean difference scores that were obtained under the four treatment conditions. Table 4 contains the mean difference scores for each unit of subject material.

The summary of the analysis of variance is represented in Table 5. All of the main effects (sequence of instruction methods, intelligence, and subject material) were found to be significant. ($P < .05$).

The two-way interaction effects (sequence x intelligence, sequence x subject material, and intelligence x subject material) were all significant at $P < .05$ level of confidence.

TABLE 3

MEAN DIFFERENCE SCORES FOR SUBTESTS IN THE HIGH AND LOW INTELLIGENCE GROUPS RUN UNDER THE FOUR EXPERIMENTAL CONDITIONS

	Treatment Groups							
	TM→C		C→TM		TM→TM		C→C	
Intelligence	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo
Diff.Score	23.34	57.50	12.67	25.32	15.75	32.00	32.99	14.00

TABLE 4

MEAN DIFFERENCE SCORES FOR STUDENTS IN THE HIGH AND LOW INTELLIGENCE GROUPS AS A FUNCTION OF SUBJECT MATERIAL

	1st half Fractions		2nd half Fractions		1st half Decimals		2nd half Decimals	
Intelligence	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo
Diff.Score	9.00	15.17	25.25	34.92	29.09	52.16	22.08	26.25

TABLE 5

SUMMARY TABLE

ANALYSIS OF VARIANCE PERFORMED
ON THE MEAN DIFFERENCE SCORES

Source of Variance	SS	df	MS	F
Within Subjects				
(A) Sequence of Instruction Methods	872.02	3	290.67	10.41*
(B) Intelligence	270.73	1	270.73	9.70*
A x B	1,329.58	3	443.19	15.87*
Subj.: W.Groups				
(error: within)	1,339.65	48	27.91	
Between Subjects				
(C) Subject Material	1,349.20	3	449.73	11.58*
A x C	1,761.82	9	195.76	5.04*
B x C	316.85	3	105.62	2.72*
A x B x C	499.94	9	55.55	1.43
C x Subj.; W.Groups (error: between)	5,590.77	144	38.82	

*P<.05

Simultaneous comparisons were performed on the marginal differences presented in Tables 3 and 4 to ascertain which of these differences were statistically significant. Tables 6 and 7 present the results of these comparisons. The results indicate that the low intelligence subjects run under the TM→ C condition, demonstrated the greatest amount of learning (viz., values listed under column 8), and that the low intelligence Ss demonstrated the greatest amount of learning during the 1st half of the decimals unit (values in column 8).

TABLE 6

POST HOC SIMULTANEOUS COMPARISONS OF MARGINAL DIFFERENCES* (IQ x Teaching Method)

Order	1	2	3	4	5	6	7	8
	c	h	e	a	d	f	g	b
Means:	12.67	14.00	15.75	23.34	25.32	32.00	32.99	57.50
g	-	1.33	3.08	10.67	12.67	19.33	20.32	44.63**
d		-	1.75	9.34	11.32	18.00	18.99	43.50**
a			-	7.59	9.57	16.25	17.24	41.75**
e				-	1.98	8.66	9.65	34.16**
h					-	6.68	7.67	32.18**
b						-	.99	25.50**
c							-	24.51**
f								-

S_b - 5.28

Range							
$Q_{.95}$ (r, 48)	2	3	4	5	6	7	8
	2.85	8.43	3.77	4.01	4.20	4.35	4.58
S_b $Q_{.95}$ (r, 48)	115.04	18.06	19.91	21.17	22.17	22.97	24.18

*Newman-Kuels Test: Winer, B. M. (2), Statistical Principals in Experimental Design.

$P<.05$

TABLE 7

POST HOC SIMULTANEOUS COMPARISONS OF MARGINAL DIFFERENCES*
(IQ x Subject Matter)

Crder:	1	2	3	4	5	6	7	8
	a	b	g	c	h	e	d	f
Means:	9.00	15.17	22.08	25.25	26.25	29.09	34.92	52.16
a	-	6.17	18.08	16.25	17.25	20.09	25.92	43.16**
b		-	6.91	10.08	11.08	13.92	19.75	36.99**
g			-	3.17	4.17	7.01	12.84	30.08**
c				-	1.00	3.84	9.67	26.91**
h					-	2.84	8.67	25.91**
e						-	5.83	23.07
d							-	17.24
f								-

S_b - 5.28

Range	2	3	4	5	6	7	8
$Q_{.95}$ (r,48)	2.85	3.43	3.77	4.01	4.20	4.35	4.58
S_b $Q_{.95}$ (r, 48)	15.04	18.06	19.91	21.17	22.17	22.97	24.18

*Newman-Kuels Test: Winer, B. J., (2) Statistical Principals in Experimental Design.

**P<.05

The instruction time required to complete the fraction and decimal units for the Ss receiving machine and classroom instruction is summarized in Table 8. Subjects on the average took one-third as much time to complete the units of instruction when receiving machine instruction than when receiving classroom instruction (P<.05).

To evaluate the relationship between performance during machine instruction and the amount of learning, correlations were performed between the acquisition data or machine data (errors/frames/minutes) and the difference scores for the high and low

TABLE 8

A COMPARISON OF THE TIME REQUIRED TO COMPLETE INSTRUCTION UNITS

	Machine (25 min. session)	Classroom (50 min. session)
1st half Fractions	5.88 hrs.	20.00 hrs.
2nd half Fractions	9.46 hrs.	27.17 hrs.
1st half Decimals	4.84 hrs.	14.17 hrs.
2nd half Decimals	5.55 hrs.	19.17 hrs.
Average	M - 6.43 hrs.*	M - 19.38 hrs.*

*t - 12.95 / 2.32 - 5.58 (P <.05).

intelligence Ss. The results of these correlations appear in Table 9. Significant positive correlations (P<.05) were obtained for the high intelligence Ss over the first and second halves of the decimal unit, and for the low intelligence Ss over the two halves of the fractions unit.

TABLE 9

CORRELATION COEFFICIENTS BETWEEN MEAN NUMBER OF ERRORS/FRAMES/MINUTES AND MEAN DIFFERENCE SCORES FOR THE HIGH AND LOW INTELLIGENCE Ss

		Subject Material			
		1st half Fractions	2nd half Fractions	1st half Decimals	2nd half Decimals
Intelligence	High	.45	.59	.92*	.80*
	Low	.90*	.85*	.41	.02

*P <.05

Discussion

Three factors were taken into account in the analysis of variance: (1) Sequence of instruction methods (C→C, C→TM, TM→TM, TM→C); (2) units of instruction (fractions and decimals); and (3) intelligence (high and low). Table 3 presents the appropriate mean difference scores that were obtained under each of the conditions.

The summary of the analysis of variance is represented in Table 5. Three main effects were found to be significant ($P<.05$): the sequence of instruction, the complexity of the units of instruction, and the intelligence level of the students. The significant sequence of instruction effect affirms the reported concept that automated methods are superior in the over-all learning effect to conventional methods. The marginal totals of Table 3 indicate an ordering effect among the presentation modes. In terms of effectiveness the rank ordering would be C→TM lowest, C→C, TM→TM, and TM→C highest. The obvious relation is that TM either alone or followed by C is a more effective type of presentation for physically handicapped students than is C alone or the C→TM arrangement.

The significant units of instruction effect illustrates that the mean difference scores increase as the content complexity increases, an expected a priori relationship.

The third main effect, intelligence, demonstrates that the lower IQ groups derive a greater benefit from TM instruction than from C alone.

All of the two-way interaction effects, sequence x intelligence (A x B), sequence x subject material (A x C), and intelligence x subject material (B x C), were found to be significant ($P<.05$). Simultaneous comparisons were performed on the marginal differences presented in Table 3 and Table 4 to ascertain which of these differences were statistically significant. Tables 6 and 7 contain the results of these post hoc comparisons. The sequence x intelligence (A x B) interaction effect (Table 6) suggests that the TM→C sequence (viz., the values listed under column 8) demonstrated the greatest amount of learning. In fact, differences occur in the lower IQ groups in all the treatment sequences. However, the differences are significant only in the TM→C group. This suggests that the lower IQ groups derive the greatest benefit from the automated learning techniques when presented in tandem with C.

The B x C interaction (Table 4 and 7), Subject Material by Intelligence, show that the brighter students in this handicapped group did effectively use the automated method although not as effectively as the duller student. As the complexity of the content increased the brighter group derived more benefit from classroom interaction. The duller students continued to show positive incremental changes throughout, with the automated methods being definitely superior.

This suggests that task complexity, as related to abstract concepts, may be more effectively handled in the classroom setting for the brighter students.

The instruction time required to complete the fraction and decimal units for the Ss receiving machine and classroom instruction is summarized in Table 8. Ss on the average took one-third as much time to complete the units while receiving machine instruction than when receiving classroom instruction ($P < .05$). When this result is considered, together with the amount of learning demonstrated under the two teaching modalities (i.e., Ss learned as much, or more, when with TM than with C) the TM method would appear to be the more efficient teaching modality.

The physically handicapped group included in this study responded differentially to the teaching methods used and to the complexity of the content.

Conclusions

The use of automated visual instruction with the severely physically handicapped in teaching arithmetic fractions and decimals was effective in the following areas:

1. Sequence of instruction. When automated instruction was used in tandem with classroom instruction, the greatest gain was found in the sequence of teaching machine followed by classroom instruction. The next greatest gain was found in the group which used the teaching machine exclusively for its instruction.

2. Intelligence factor. Automated instruction alone provided more benefit to students in the lower intelligence groups than did classroom instruction alone. All students derived the greatest benefit from automated instruction when it was followed by classroom instruction, however, the higher intelligence students benefited from automated instruction, but not to the extent of the lower intelligence groups.

3. Instructional time. Automated visual instruction over the same content as conventional instruction required approximately one-third as much time as conventional instruction.

4. Mechanical. Teaching machines can be adapted to the needs of severely handicapped students by use of proper control devices.

Implications

Automated visual instruction can be effective in four problem areas with this population: (1) Time available for instructional purposes, (2) Compensation for interruptions of learning continuity, (3) Provision for meeting the multi-grade levels in each classroom, and (4) Provision for multi-level content.

Time for Instruction. Teaching machine instruction is more efficient than conventional instruction with this population. In a situation where time for instruction is reduced due to medical and surgical priorities the teaching machine mode is effective in maintaining educational progress.

Compensation for Interruptions of Learning Continuity. Automated instruction is under control of the student. Where interruptions of learning are caused by fatigue, pain, illness, surgery, or therapy, the student may review or proceed with the subsequent task without educational content loss upon returning to the learning situation. Teacher absence has little affect on continuity.

Provision for Meeting the Multi-grade Levels in Each Classroom. Small classes require combinations of several grades with achievement spans of several years. Automated programs can permit individual students to work independently at their appropriate grade levels.

Provision for Multi-Level Content. Teaching machines have the capability of providing a variety of subject content to suit curriculum or individual needs. Adequate automated instruction can also be offered a student in a subject in which the instructor lacks competence.

Recommendations

One of the major purposes of the study was to generate researchable problems involving the use of automated instruction with the severely physically handicapped which would outline a program for further study. During the course of the experiment and analysis of results, a series of questions began to emerge in three broad categories involving machine, subject, and content variables.

Machine Variables. The teaching machine used in the experiment operated on a multiple-choice basis. Would a single choice response have accounted for similar results?

The arithmetic programs used in the machines were prepared and keyed to the machine operation. The concepts were presented in sizeable portions with sub-concepts and exercises for reinforcement. Would the size of the learning step, either larger or smaller, have altered the findings?

The design called for the use of the teaching machine in conjunction with classroom teaching. When is automated teaching more effective than classroom teaching?

An effort was made to control for the effect of novelty in the construction of the design. However, the novelty effect of the teaching machine was not part of the experiment. What is the novelty aspect of automated teaching and does it influence performance?

The Autotutor allows for a limited branching or looping, linear program. Would a machine with greater flexibility offer more stimuli for response? Would a machine with true branching, color, and sound capabilities provide better response?

Subject Variables. If the introduction of concepts had been in a more gradual form would the levels of intelligence continue to be important variables?

Students in the classrooms operated the machines within the confines of 4' x 4' booths which served partially to isolate them. Does the reduction of sociability influence the efficiency or effectiveness of machine teaching?

Is there a different learning process used by brighter than that used by duller students?

Content Variables. Where the teaching machine is used in conjunction with conventional teaching, what are the parameters of interaction with the teacher and the course content?

Can automated instruction be applied more effectively to remediation, maintenance of skills, or extension of skills in a hospital setting?

Summary

Twenty-eight paraplegic, quadruplegic, cerebral palsied and other severely physically handicapped secondary students, who were patients in the Los Angeles County Rancho Los Amigos Hospital, were included in a study of the effectiveness of automated visual programed instruction. Subjects were divided into four groups matched in terms of reading level and intelligence. Four treatment modes were used to teach arithmetic fractions and decimals. Two groups alternated between teaching machines (TM) and classroom (C). One group remained continuously with the teacher and one continuously with the machines. Machine controls were adapted to disabilities.

Independent variables were: (1) instruction materials with units split at mid-point providing fourunits--instructional contents used by machines and teachers were identical; (2) modes of instruction; (3) matching criteria, reading level, and intelligence.

Dependent variables were: (1) time required to complete units; (2) performance in terms of mean difference scores (i.e., pretest, midtest, posttest); (3) rate of learning and percent of errors.

Findings: (1) TM mode of instruction was about two-thirds more efficient in time; (2) TM mode was most effective in tandem with C mode; (3) TM mode was most effective with lower intelligence Ss; (4) C instruction mode became more effective as instruction material became more complex (difficult); (5) the most effective sequence is TM followed by C instruction; and (6) operation of machines can be adapted to disabilities.

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7. AutoTutor Operator's Handbook, Silver Spring, Maryland: U. S. Industries, Inc., 1964.

Appendix A

Subsequent to the termination of the project, the Autotutor and Tutorfilm were purchased by The Welch Scientific Company, 7300 N. Linden Avenue, Skokie, Illinois, 60078.

Appendix B

C O P Y

Air Mail

June 10, 1965

Joe Glenn Coss, Ed.D.
Director of Research
Downey Unified School District
11627 Brookshire Avenue
Downey, California

Dear Dr. Coss:

Thank you very much for your letter of June 1st in which you request permission to modify the machines manufactured by this Division and leased from the Welch Scientific Company.

This Division hereby grants you permission to modify machines in accordance with your letter, with the understanding that the AutoTutor teaching machines will be returned to their original condition at the termination of the lease period. You are to bear full costs for the modifications and for the return to original condition.

In addition, as we discussed by telephone, you would make available to this Division's Research Department a description of the results of your research experiment as well as the design schematic that you use in the modification.

Listed below is the name and address of the author who participated in the writing of the Career Arithmetic modules. Please feel free to communicate with him direct. Hopefully, he will be able to provide you with the information you desire.

Our meaning of the statement that the materials written on a 7th grade level refers to reading level and not to mathematics achievement. Simply, if a person who has achieved a reading level of the 7th grade or higher, but has not attained an arithmetic competence to deal with these different subjects may, by study of these materials on the AutoTutor teaching machine, achieve such competence.

C O P Y

My very best wishes to you in your experiment. I look forward anxiously to your report.

Sincerely yours,

/s/ Herbert S. Parker

Herbert S. Parker
Vice President, Sales

HSP:blb

cc: Mr. Lester Bolton, Welch Scientific Co.
Mr. Elton Lash, Welch Scientific Co.
Dr. Richard Walther, Director, Department of Research, USI/ESD

Author to Contact Re: Career Arithmetic Modules

Mr. William Caulfield
c/o MacMillan Company
60-62 Fifth Avenue
New York, New York 10011

Appendix C

Non-Handicapped Students

The design of the project called for a control of non-handicapped students who would be matched as nearly as possible with the severely handicapped students in the hospital.

The handicapped had been given the WAIS or WISC and the STEP Form 3A reading test. Forty-eight handicapped students had reading scores above the qualifying limit, which was the seventh grade reading level recommended for machine lesson comprehension.

The content of the TutorFilm mathematics series fell naturally within the 7th, 8th, and 9th grade range. West Junior High School, nearest to the hospital, was selected for the control. The permanent record cards of students registered in arithmetic classes were examined, and those which did not come within the age and intelligence range were screened out. The remainder were given the STEP Reading Test, Form 3B to establish reading placement.

Since age was not a deciding factor in the hospital, grade placement, sex of student, reading score, and intelligence provided matching criteria.

The handicapped were found to be generally two years behind their expected age-group placement so the non-handicapped were generally younger. Forty-eight handicapped students were qualified during the summer and forty-eight non-handicapped were relatively matched. Subsequent discharges reduced the N of the handicapped, and one non-handicapped transferred from the district.

The non-handicapped Ss had the following grade placement: 19 seventh grade, 17 eighth grade, and 11 ninth grade.

The questions which were asked for the handicapped population were also asked for the non-handicapped, but the principal purpose of the control was to examine the relationships and interactions of non-handicapped to the same instructional modes as the handicapped.

The experimental classroom was a portion of the school library. Four isolation booths were aligned against one wall. Four teaching machines were placed at eye-level on student tables, one to each booth.

The design called for groups not larger than eight in number. Class periods were 52 minutes long. This permitted each S to spend about 25 minutes a day on a machine. Four would use the machines while the other four would work on other subject areas under supervision.

The design for the handicapped students called for a change of instruction mode midway through each sequence. The teachers would not accept so much student movement, so the change of instruction mode came at the end of the quarter for the non-handicapped. The teachers did not use the text prepared to parallel the machine lessons.

The control was divided into four groups. The first group, N-16, used the teaching machine for eight weeks, and most subjects covered the instruction on fractions and decimals in that time. The Ss then returned to their teachers for the second quarter.

A second group, N-15, had received instruction from teachers for the first quarter and started on teaching machines at mid-semester. They covered the instruction on Percentage and most of Ratio and Proportion.

In order to assess any effects from changing from one mode of instruction to another, a third group, N-8, continued with machine instruction for the semester. The fourth group, N-8, remained with the teachers for the semester without any experience on the machines.

It was necessary to determine the arithmetical knowledge of the subjects prior to instruction. The AutoTutor diagnostic surveys for whole numbers, fractions, decimals, percentage, and ratio and proportion were used. The A form was selected for use as pretest, midtest, and posttest to provide constant measurement of Ss' abilities.

Data were carefully recorded, and it was not until the project was well advanced did it become evident that significant statistical relationships between machine and classroom performance could not be made.

Anecdotal Observations of Behavior

Eighteen of the thirty-nine students who had machine instruction made consistent progress, worked with concentration, accepted their errors and lesson corrections, and the occasional forced repetitions. On the whole these students hadbetter reading scores.

Some students had the initial concept that they need merely sit before the machine passively and it wouldimpart knowledge to them. They were quickly disabused of this notion when they began to experience this mode of instruction. The reactions could be broadly categorized as motivational and frustrational.

Motivational Behavior. The initial lessons of each program were based on the assumption that the learner had no previous experience with the material. For those who had had experience, the first lessons were easy and confidence-building. All students were initially enthusiastic and eager to work on the machine. Novelty and status provided initial motivation. As the novelty diminished the students accepted the routine of the class period. At the end of the first four weeks there was no evidence of reluctance to work with the machines.

Some students became competitive and began to compare frame numbers and number of errors. The effect on a few of the students was indiscriminately to speed up response. Students had three or four alternative choices for each question. Without reading the context they could proceed, if they chose, to push buttons, returning as necessary, until the correct response permitted them to proceed to the next concept.

Another factor of competition was noted. As members of the class finished a program, the slower students began to hurry their responses. Usually this lead to errors which penalized them and forced them further behind.

Frustrational Behavior. As the programs developed in complexity, and began to introduce concepts with which the students were unfamiliar, evidence of frustration appeared.

The AutoTutor manual of instructions warns the teacher to check carefully and assist the student if an excessive number of errors are recorded. Since this was a controlled experimental situation, the investigator did not interfere unless the student was repeating the lesson for the third time.

Some students began to use notebooks to record their responses Each frame contained its number. The student would write down the frame number, and then would proceed to work the problems and otherwise determine the correct response. If his response were correct he would jot down the correct response for that frame. In some cases he merely guessed at the response without reading the lesson or working the problem. In this manner he could finally reach the test at the end of the lesson. The program was so designed that if he missed two or three questions on a five question test he was told that he needed to review the lesson. There was no way he could proceed to the next lesson without passing the test. Since he had recorded his wrong responses he could eliminate them.

When he began to review the lesson he merely checked his notebook, selected the right response, and thus could reach the test again in a few moments. By using this method the student could by-pass most of the learning of the program, if he chose.

Appendix D

C O P Y

13 October 1965

Dr. Joe Glenn Coss
Research Director
Downey Unified School District
11627 Brookshire Avenue
Downey, California

Dear Dr. Coss:

This letter is in response to your letter of September 16, 1965, to Dr. Parker requesting permission to mimeograph twelve copies of the TutorFilm* course Career Arithmetic Series: ESD 340-1-4 Building Skill with Whole Numbers, 340-5 Fractions, 340-6 Decimals, 340-7 Percentage, 340-8 Ratio and Proportion.

We are pleased to grant permission to the Downey Unified School District to reproduce up to 25 copies of the above mentioned program for the purpose of conducting a research project under a grant from the U. S. Office of Education. It is understood that this permission is granted for the purposes of the experiment and only during the period of the experiment. The above named experiment being titled "Effectiveness of Automated Visual Programmed Instruction with Paraplegic and Other Severely Handicapped Students", and the period of the experiment extending from June 1, 1965, to November 30, 1966. It is also understood that the materials so reproduced will not be for sale and are not to be reproduced in excess of 25 copies.

I read with a great deal of interest your proposal to the U. S. Office of Education. You are, I believe, attacking a very significant problem in this study, one which I feel will have important implications for all teachers of the handicapped. Dr. Parker and I are looking forward to hearing from you further on your progress and results of this study.

C O P Y

Dr. Joe Glenn Coss -2- 13 October 1965

Please call on us if there is any way in which we can assist you further.

In regard to your question about the new mathematics, we are presently developing programs in that subject. We expect them to be released sometime in 1966.

With best wishes for a successful project, I am.

Sincerely yours,

/s/ Isadore Goldberg
Isadore Goldberg, Ph. D.
Director of Educational
Development

IG/mz
cc: Dr. Parker