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PROGRAMED INSTRUCTION FOR A PRODUCTION ASSEMBLY TASK

by

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INTRODUCTION

One of the various problems encountered in industry is that of instructing or training workers. A new worker or a new job for an old worker requires that the worker go through a learning process to enable him to correctly function in his new job. Often the work instruction is given as a written or typed list of steps which has been developed by the organization's industrial engineering department. Sometimes the worker is given a blueprint from which to obtain his work instructions.

One method of attacking the training problem is used by the auto industry. Where cars are mass produced, the problem is solved by dividing the total job into very small increments and hiring as many people as there are increments. Each performs many repetitions of these small increments of the total job. By the coordination of many workers, the autos are mass produced. However, there are many assembly tasks which do not lend themselves to this technique, because of complex design, limited production, short product life, or some other factor requiring considerable knowledge and skill on the part of a worker. Increasing need for training and instructing workers has brought about new interest in the learning process and methods of instruction for assembly tasks.

To study the learning process is to stand upon ground that is not completely explored. Bugelski (1), a psychologist, has said "A scientific theory of learning has yet to be agreed upon by psychologists".

Recently, a new method of teaching, programmed instruction or programmed learning, has emerged. The pioneer psychologist in programmed instruction is Sidney L. Pressey (11). Pressey was an Ohio State University psychologist who designed a machine for testing purposes in the early 1920's. He exhibited his device and presented papers discussing it at the meetings of the American Psychological Association in 1924 and 1925. His invention was a mechanical device for administering and scoring tests. It was designed to incorporate the known principles of the learning process into a mechanical device which would do some of a teacher's routine work and give the teacher added time to concentrate upon the more creative parts of his work. Following his first work, Pressey and his students at the Ohio State University continued to develop additional devices and to try these out experimentally with a variety of course materials. Pressey continued his work and wrote a few papers in the 1930's and 1940's, but the "industrial revolution" in education which he visualized did not take place until about thirty years after his first paper was presented.

In 1954 B. F. Skinner (11), a Harvard psychologist, presented his paper "The Science of Learning and the Art of Teaching". His thesis is that the whole process of becoming competent in any field of endeavor must be divided into a very large number of very small steps and reinforcement must be contingent upon the accomplishment of each step. He also had the design for a mechanical device to present his program to a student. The next decade witnessed an active attempt to implement his philosophy in practice by producing programs and machines to present and control the programs as used by a student. In fact, the term "teaching machine" seems to have emerged during this period and attached itself to the initial term of programmed instruction. Now the term used for the industry is "Teaching Machines and Programmed Learning". Although the word "teaching machine" is a misnomer, it appears in the literature. A teaching machine is a mechanical, electrical, or electronic device that controls the presentation of the program, keeps a record of the student's answers, and provides immediate feedback by displaying correct answers. A definition for "programmed instruction" is now due.

Hughes (8) gives this definition:

> Programmed instruction is any form of pre-prepared, pre-sequenced instruction directed toward a specific educational or training objective.

Characteristics of programmed instruction:

1. Each student works individually on the programmed instruction materials at his own pace.

2. A relatively small unit of information is presented to the student at a time. A statement to be completed, or a question to be answered, about this information is also included. This is known technically as the stimulus.

3. The student is required to complete the statement or answer the question about that specific bit of information. In technical terms, he is said to be making a response to the stimulus presented. The statement or question is usually designed to make it probable that the student will give the correct response.

4. The student is then immediately informed whether his response is correct or not. If it is wrong, he may also be told why. By this kind of feedback, he is

rewarded (told he is correct) if he gives the correct answer; in more technical terms, his response is reinforced. In learning experiments, psychologists have found that reinforcement increases the probability of making the correct response to the same stimulus in the future.

5. The student is next presented with the second unit of information, and the cycle of presentation-answer-feedback or, more technically, stimulus-response-reinforcement of the correct answer is repeated. The same cycle is repeated again and again as all of the necessary information is presented in a logical sequence. Provision is also made for the practice and review of previously learned information.

Each unit of information presented is called a frame, because when teaching machines are used, the information appears through a window on the machine. A series of such frames, presenting a logical sequence of information, is called a program. Programs may run into hundreds or even thousands of frames, which present the subject matter step by step in a logical order, beginning with the simpler concepts and advancing to the more difficult. When the student has to compose the entire response, it is known as a write-in, or constructed response, program. In another kind of program, the student is presented with a number of alternative responses to the question asked in a frame and is required to choose the correct one. This program, similar in format to an objective achievement test, is known as a multiple-choice response program. For some programs, all students work through the same fixed sequence of frames determined by the program writer. A program of this sort is called a straight-line, or linear, program. For other programs, each student follows a sequence of frames determined by his own responses. Such programs are called branching programs.

Generally, then, programs differ in two respects: the mode of response (constructed-response or multiple-choice) and the sequence of frames (linear or branching). All existing programs can be classified according to these two characteristics. Most of the programs written at present are of the constructed-response, linear variety. In general the applications for an assembly task are of the constructed-response, linear type of programs.

The branching programs are direct decendants of Pressey's multiple choice testing programs. N. A. Crowder has developed programs of the multiple choice response and branching type based on what he calls intrinsic programming principles. Intrinsic programming means that each student determines the sequence of frames by his responses to the multiple-choice questions contained in the frames.

Since Skinner's paper in 1954, a variety of programs have been produced and used in a variety of situations and age groups. Programs have been used in schools, in industry, in the military, and in home study. Hughes (8) says, "In almost every case where it has been used, programmed instruction has led to either a reduction in learning time or an increase in the knowledge or skill acquired by students, or both".

In his 1962 survey of the industry, Finn (4) lists 137 companies. These companies are producers of programs, writers or programs, manufactures of hardware, consultants, or a combination of these functions.

In a survey of the research, Schramm (13) estimates that since 1954 there have been approximately 190 reports of original research on programmed instruction. Of the 160 papers he compiled information from, only 18 involved a work related task. Since a certain manufacturer (17) claims that its communication system can reduce production time, training time, and rejects, and little research has been done to investigate the application of programmed instruction to production assembly tasks, there is a need for research in this area. The remainder of this thesis will be concerned with programmed instruction for a production assembly task.

A comparison of the production assembly task work instruction program design criterion and characteristics of programmed instruction reveal similarities. Both have a specific instruction or training goal. While it is not always feasible to describe the training objective for some subjects, the production assembly worker has a definite specified product to produce from his work. Both call for an ordered sequence of items through which the student works in short steps. The nature of the product will usually dictate the order of assembly and the worker must respond to each item to build the product. Both call for the operator working at his own pace. Since the product is produced to specifications, the operator gets feedback from inspections to reinforce his responses.

Recent studies (9,10) in the application of programmed instruction to assembly tasks have shown a significant decrease in assembly time for workers using 35 mm color slides projected in a Hughes Videosonic unit for their work instructions when compared with conventional typed running lists. The term work instruction is used to indicate that the operator responds to the program for the assembly of each unit and usually doesn't attempt to memorize the steps. Some of these programs (17) in use in industry have 3210 separate steps and require 65 hours to complete a unit. In fact, for programs of this type, because of their length, the operators are requested to refrain from trying to memorize parts of the program and rely entirely upon the programs to insure uniformity and quality in the product.

Since slide projection equipment costs from $100 to $600, it would be economically desirable to have work instruction programs which would still result in a decrease in production time but which would not involve the use of projection equipment. It has been demonstrated that with certain equipment reduction in errors and assembly time can be expected. This experiment was an effort to obtain the desirable results of this type of work instruction without the investment in special equipment. A cheaper type of program, if proved effective, could be used on jobs which could not economically justify the investment in projection equipment.

The idea that photographs can be used to increase the effectiveness of instructional programs is not new. As early as 1936, Williams (16) cites an example in which photographs were used in an instructional program for workers in a shoe factory.

METHOD

Task Studied

PLATE I shows the pegboard and parts used in the experiment. The board consisted of sixteen vertical dowels which formed a four by four matrix. The four rows were labeled 1, 2, 3, and 4. The four columns were labeled A, B, C, and D. A layer was formed by assemblying nine parts on the base. There were three different kinds of parts. These parts were named singles, doubles, and triples, depending upon how many holes were in the part. The nine parts for a layer were five singles, four doubles, and one triple. Singles were painted red on one side and white on the other side, while the doubles and triples were painted red on one end of one side and white on the opposite end of the other side. Each of the three different tasks consisted of two different layers assembled on two different boards. Each layer of each task was a combination of the same number and kind of parts. Each subject assembled thirty six cycles for each of the three tasks and used a different instructional medium for each task.

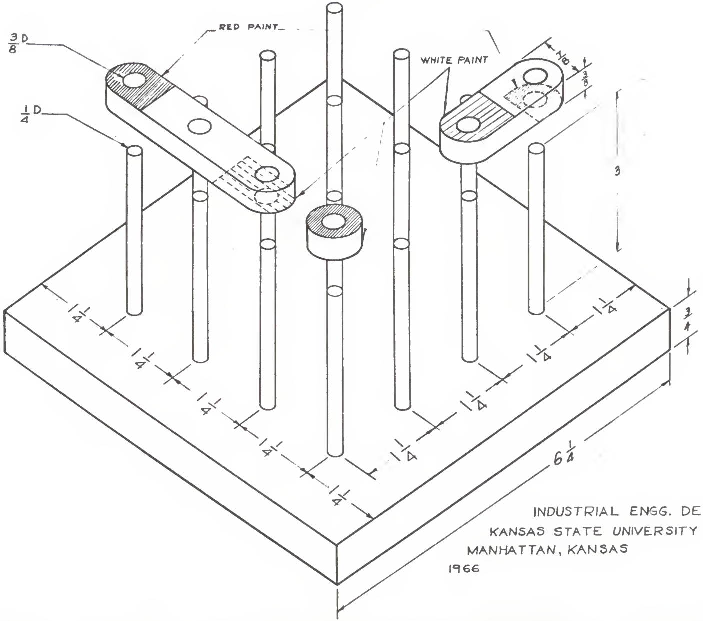
Work Instruction Programs

Three different methods of giving the subjects the information needed to assemble the tasks were used; Photographs, Model, and Listing. The three tasks were labeled 1-2, 3-4, and 5-6. Photographs, Model, and Listing programs were made for each of the three tasks. The photograph programs consisted of two five by seven color photographs of completed layers. Earlier studies

EXPLANATION OF PLATE I

Pegboard type base and three different types of parts used in experiment.

PLATE I


RED PAINT
WHITE PAINT
3/8 D
1/4 D
3/8
3/8
3
1 1/4
3/4
6 1/4
INDUSTRIAL ENGG. DEPT.
KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS
1966

(9,10) used a Hughes Videosonic unit to project the color slides on a back projection screen for the subject. The photographs used were a standard size processed by Kodak and were slightly smaller than the Videosonic screen. Since economy of program cost is desired, the standard size was preferred. A sample of this type of program is shown as PLATE II.

The model programs consisted of two completed layers which were placed before the subject on the work place opposite the part bins. On PLATE III, the top picture shows the work place set up for use of the model program.

The listing programs were typewritten lists of the instructions needed to assemble each of the two layer tasks. The lists used the column and row labels to identify each one of the sixteen dowels. A sample of this type of program is shown on PLATE IV. Note that colors in the inspection sheet did not reproduce. The red, white and wood had high contrast in the actual inspection sheet.

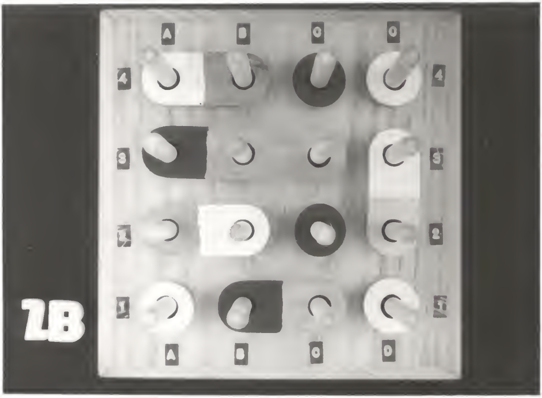
Subjects

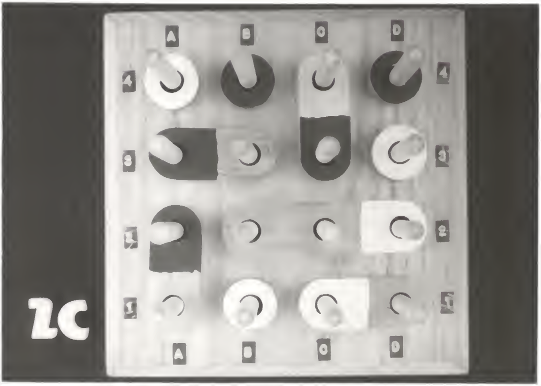
Eighteen subjects were obtained through the Kansas State Employment Service and from Kansas State University students who responded to circulars posted at various locations on the campus. Since a large portion of the production assembly work in the electronics industry is performed by women, only female subjects were used. The average age was approximately twenty years with a range from 18 to 22 years. The average number of school years completed was 13.8 with a range from 12 to 16.5. The subjects

EXPLANATION OF PLATE II

Photographs program for task 1-2. The top photograph was for layer 1 and the bottom photograph was for layer 2. For the experiment, 5 by 7 inch color photographs were used.

PLATE II

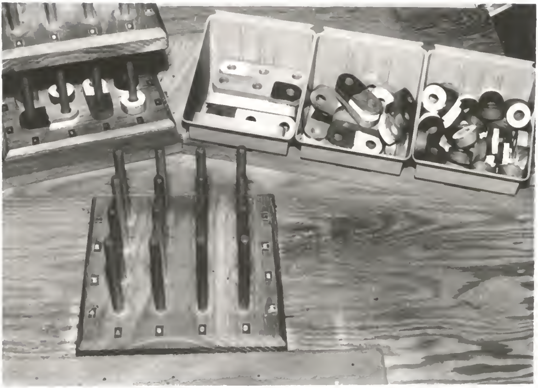




EXPLANATION OF PLATE III

Top photograph shows the work-place used in the experiment set up for use of the Model program. Bottom photograph shows subject picking up first part to begin an assembly cycle.

PLATE III



EXPLANATION OF PLATE IV

Top: Listing program for Task 1-2.

Bottom: Inspection sheet for Task 1-2. Colors did not reproduce. Inspection sheets were red, white, and natural wood. Sheet is shown actual size.

PLATE IV

Task 1-2

1. Get 5 singles
2. White a A1, D1, D4
3. Red at C2, C4

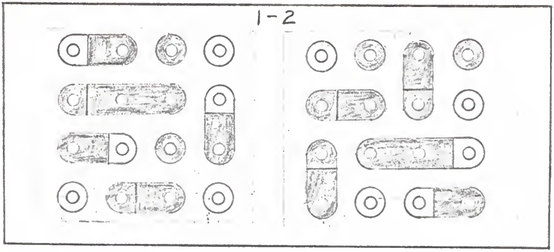
4. Get 4 doubles
5. White up at D2, D3
6. White right at A2, B2
7. White left at A4, B4
8. Red left at B1, C1

9. Get 1 triple
10. Red left at A3, B3, C3

11. Get 5 singles
12. White at A4, B1, D3
13. Red at B4, D4

14. Get 4 doubles
15. White left at C1, D1
16. Red up at A1, A2
17. Red down at C3, C4
18. Red left at A3, B3

19. Get 1 triple
20. White right at B2, C2, D2



were paid $4.00 for their work, and, on the average, they worked for about three hours.

Work Place

The standard work place used by each subject is shown as PLATE V. The part bins were placed on the right hand side for right handed persons and placed on the left hand side for left handed persons. PLATE II shows a subject at the work place.

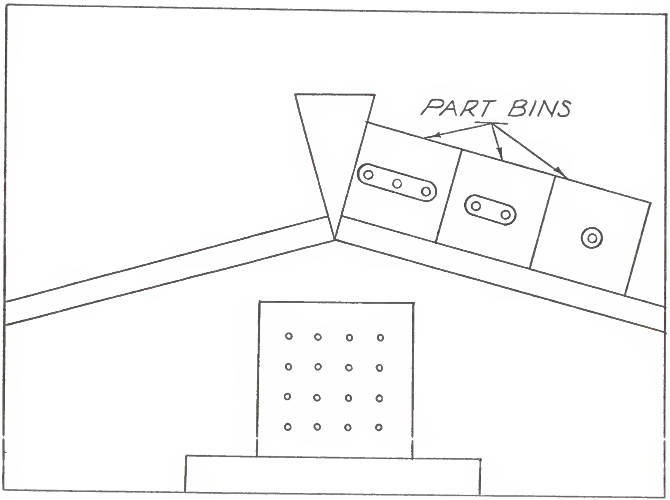
Data Format

Each layer that a subject assembled was timed and checked for errors. The time was measured from the instant the subject reached for the first part until the last part was in place. Time was measured with a decimal minute stop watch and was recorded to the nearest 1/100 of a minute. Each layer was inspected by comparing it to a standard. The standard was a minature color-coded top view of a task. The inspection sheet for task 1-2 is shown on PLATE IV. Errors were classified five ways: position (on wrong pegs whether up one peg, down one peg, right one peg, or left one peg), orientation (on correct pegs but with ends reversed or part upside down), color (on correct pegs but with wrong color showing), omission (part omitted), and other (any error which did not fit into the above categories). Parts could be out of position more than one peg in a direction or parts could be over-lapped by putting more than one part on a peg. If, for some reason, the entire layer was incorrect, it was scored as nine "other" errors. To facilitate the collection of

EXPLANATION OF PLATE V

Top view of workplace showing positioning boards and part bins. Workplace is set up for right hand worker. Workplace is shown one-fourth size.

PLATE V



EXPLANATION OF PLATE VI

Top half of data form used in the experiment. The block just to the right of the word "layer" was for recording the time for a layer. The frequency of errors was recorded in the appropriate blocks. One data form was used for twelve layers.

PLATE VI

Kansas State Univ.
I.E. Dept. Feb. 66

Date ______

Condition ______ Task ______ Subject ______

Carl McCutchan

Layer		S	D	T	Layer		S	D	T	Layer		S	D	T
Pos.	RI				Pos.	RI				Pos.	RI			
	LI					LI					LI			
	UI					UI					UI			
	DI					DI					DI			
	other					other					other			
	orien.	X				orien.	X				orien.	X		
	omiss.					omiss.					omiss.			
	color					color					color			

Layer		S	D	T	Layer		S	D	T	Layer		S	D	T
Pos.	RI				Pos.	RI				Pos.	RI			
	LI					LI					LI			
	UI					UI					UI			
	DI					DI					DI			
	other					other					other			
	orien.	X				orien.	X				orien.	X		
	omiss.					omiss.					omiss.			
	color					color					color			

data, data sheets were printed with space available for recording the time, the kind of errors, the number of errors, and what type of part (single, double, or triple) was involved. A sample data sheet form is shown as PLATE VI.

Design of Experiment

The purpose of the experiment was to test the effectiveness of three different types of work instruction programs. The effectiveness was measured in terms of the time used to assemble the units, the frequency and type of errors found in completed units, and preference of subject.

Learning, fatigue, and change in the subject's interest in the experiment were taken into account by the experimental design. Each subject served as her own control by assemblying units using each of the three types of programs. The order in which the subjects used the three programs was counterbalanced. That is, three subjects used each of the six sequences: photographs-model-list, photographs-list-model, list-model-photographs, list-photographs-model, model-photographs-list, and model-list-photographs. The three tasks, 1-2, 3-4, and 5-6, were balanced into these six sequences. Each task was used first six times, second six times, and last six times. The subjects were assigned to the sequences by use of a random number table. Table 1 shows a schedule of the sequences as they were used by the subjects.

The work was done by each subject at one session. Each subject assembled 36 two layer tasks for each of the three media. When the subject had completed her work, she was asked which

Table 1. Experimental sequence for each subject.

Subject	1st Medium and task	2nd Medium and task	3rd Medium and task
1	P-3,4	L-5,6	M-1,2
2	M-3,4	P-5,6	L-1,2
3	L-3,4	P-5,6	M-1,2
4	P-1,2	L-3,4	M-5,6
5	M-1,2	L-3,4	P-5,6
6	M-1,2	P-3,4	L-5,6
7	P-1,2	M-3,4	L-5,6
8	M-3,4	L-5,6	P-1,2
9	P-5,6	L-1,2	M-3,4
10	L-1,2	P-3,4	M-5,6
11	M-5,6	P-1,2	L-3,4
12	L-5,6	P-1,2	M-3,4
13	P-5,6	M-1,2	L-3,4
14	L-5,6	M-1,2	P-3,4
15	L-3,4	M-5,6	P-1,2
16	P-3,4	M-5,6	L-1,2
17	M-5,6	L-1,2	P-3,4
18	L-1,2	M-3,4	P-5,6

L = Listing program

P = Photographs program

M = Model program

1,2 = Task 1,2

3,4 = Task 3,4

5,6 = Task 5,6

medium she liked the best and which medium she liked the least.

The subjects were given the following instructions verbally prior to beginning their work.

1. Work quickly but accurately.
2. For the listing, you may want to keep your place with your left hand.
3. Use your preferred hand only to place the parts on the board. (other hand could be used to hold parts)
4. You may correct errors that you notice before each cycle is completed.
5. Your work will be timed and checked for errors. (the subjects were not given any feedback during the experiment)
6. For the picture programs, assemble the top layer first and then assemble the bottom layer. For the model, assemble the left layer first and then assemble the right layer.
7. Place the five singles on first, the four doubles on second, and the triple on last for each layer of each medium.

The above instructions constitute a certain work method. Each subject used the same method. The subjects still had freedom to vary the assembly method within the singles and within the doubles, but each one put the parts on in the singles-doubles-triple sequence. The experiment was subject paced.

RESULTS

The average times for the media were model: 0.339, photographs: 0.363, and listing: 0.524 minutes/layer. See Table 2, Table 4, Appendix I, and Appendix II. From the two-way analysis of variance, Table 4, it was concluded that there is a significant difference ($\alpha = 0.01$) among the media. The averages were tested with Wilcoxon Signed-Ranks Tests. The model, photographs, and listing were significantly different ($\alpha = 0.005$) from each other.

The total errors for the media were model: 34, photographs: 51, and listing: 187. See Table 3, Table 5, Appendix III, and Appendix IV. The data for errors was subjected to an analysis of variance. From the analysis of variance, it was concluded that there is a significant difference ($\alpha = 0.01$) among the media. Both model and photographs were more accurate than the listing ($\alpha = 0.005$), but there was no significant difference between the model and the photographs.

Since all of the subjects did not use the media in the same sequence, the effect of sequence was tested in the analysis of variance. For both time and errors, the effect of sequence was not significant. For time, the effect of subjects within sequence was significant ($\alpha = 0.01$). For errors, the effect of subjects within sequence was significant ($\alpha = 0.05$). This is what would be expected.

According to the opinion survey, the subjects liked the model best and the listing least. See Table 6.

Thus, from all three criteria, the model is best and the listing worst.

Types of errors for each medium are given in tables 7, 8, and 9. The two largest types of errors, orientation and color, were compared with a Wilcoxon Matched-Pairs Signed-Ranks Test (14) for the three media. See Table 10. For orientation errors, the listing was worse than the photographs and worse than the model. The photographs were equal to the model. For color errors, the list was worse than the photographs and worse than the model. The photographs were equal to the model.

During the experiment, the subjects assembled a total of 3,888 layers or 38,880 parts. Each layer was composed of five singles, four doubles, and one triple. It is interesting to note that when the parts are divided into two groups, singles and doubles + triples, a large difference is observed in the number of errors for each group. See Table 11. For each group of parts, there were 19,440 opportunities for errors. There was a total of 47 errors made on singles and 225 errors made on doubles + triples. For the model or photographs, errors increased by a factor of two when the "simple" single was made "complex". For the listing, however, errors increased by a factor of eleven when complexity was increased.

Table 2. Average time (minutes per layer) for each subject.

Subject	Photographs	Model	Listing
1	.295	.267	.471
2	.340	.345	.501
3	.392	.370	.559
4	.478	.404	.528
5	.324	.319	.394
6	.513	.426	.877
7	.338	.280	.474
8	.380	.374	.504
9	.335	.354	.522
10	.428	.405	.740
11	.252	.265	.326
12	.394	.322	.498
13	.323	.297	.440
14	.334	.332	.499
15	.335	.312	.432
16	.344	.312	.522
17	.361	.356	.563
18	.370	.359	.580
Average	.363	.339	.524

Table 3. Total errors for 72 layers for each subject.

Subject	Photographs	Model	Listing
1	2	1	9
2	1	0	0
3	1	1	3
4	1	4	3
5	2	4	32
6	9	6	34
7	0	1	7
8	2	0	12
9	2	2	9
10	1	2	8
11	6	1	0
12	8	0	12
13	1	2	2
14	5	3	10
15	1	3	4
16	3	1	19
17	1	0	3
18	5	3	20
Average	2.83	1.89	10.39

Table 4. Summary of analysis of variance for assembly times.

Source	d.f.	S.S.	M.S.	F
Between Subjects	17			
Sequence	5	0.040	0.008	0.41
Subjects within Sequence	12	0.232	0.019	7.42**
Media	2	0.364	0.182	70.00**
Residual	34	0.088	0.0026	
Total	53			

**p < .01

Table 5. Summary of analysis of variance for errors.

Source	d.f.	S.S.	M.S.	F
Between Subjects	17			
Sequence	5	72.2	14.44	0.21
Subjects within Sequence	12	830.8	69.23	2.42*
Media	2	781.4	390.70	13.67**
Residual	34	971.6	28.58	
Total	53			

**p < .01 *p < .05

Table 6. Summary of opinion survey.

	Model	Photographs	Listing
Liked best	9	6	3
Liked least	2	5	11
	+7	+1	-8

Table 7. Summary of errors for photographs.

		Singles	Doubles	Triples	Total
Position-	right one	0	0	0	
	left one	0	0	0	
	up one	0	0	0	
	down one	0	0	0	
Orientation		0	16	2	
Omission		6	2	0	
Color		14	5	1	
Other		0	4	1	
	Total	20	27	4	51

Table 8. Summary of errors for model.

		Singles	Doubles	Triples	Total
Position-	right one	0	0	0	
	left one	0	0	0	
	up one	0	0	0	
	down one	0	0	3	
Orientation		0	15	2	
Omission		3	2	0	
Color		8	0	1	
Other		0	0	0	
	Total	11	17	6	34

Table 9. Summary of errors for listing.

		Singles	Doubles	Triples	Total
Position-	right one	0	0	0	
	left one	0	0	0	
	up one	0	0	0	
	down one	0	0	1	
Orientation		0	126	10	
Omission		0	2	0	
Color		16	25	7	
Other		0	0	0	
	Total	16	153	18	187

Table 10. Distribution of orientation and color errors among media.

	Model	Photographs	Listing
Orientation	17	18	136
Color	9	20	48

Table 11. Distribution of single type errors and (double + triple) type errors among media.

	Model	Photographs	Listing	Total
Singles	11	20	16	47
Doubles + Triples	23	31	171	225

DISCUSSION

McCormick (12) says that in performing any type of work, a person engages in essentially three kinds of functions.

1. The first of these is one of obtaining information. This occurs largely through the various sense organs, especially the eyes and ears, but also through the other senses.

2. The second function is that of making decisions. These decisions are made on the basis of the information obtained through the sense organs, in interaction with the knowledge that is "stored" in the individual.

3. The third function is that of acting upon the decisions. In many jobs this action is of a physical nature, as in operating control devices or in using tools. In other jobs, this action is a communication, usually oral or written.

For the listing, the subject must gather information, interpret that information, and act upon that interpretation in the form of assemblying a part on the pegboard. He may or may not interpret the information correctly, and if he interprets it incorrectly, his response also (except by chance) will be incorrect. The information is in the form of letters and numbers. These symbols must be related to the pegboard and available parts and the correct response visualized. This process must be repeated for each step in the assembly of the unit.

For the photographs, the subject can visualize the information without any symbols and formulate his response. Because the subject can formulate his response without the use of symbols and without interpretation, he can respond faster and make less errors on the photographs program as compared to the typewritten listing.

The assembled units used as models in assemblying other units serve the same function as the photographs. However, from the data, one would suspect that the model is a little better than the photographs. This could possibly be attributed to the fact that the photographs do not give as clear information as one can obtain from looking at the model itself. Photographs could be improved by using different colors that will show proper contrast when photographed.

An examination of the summary of all errors made shows that the subject made almost no "position" or "other" errors. More than 96% of the errors made were in the "orientation", "color", and "omission" categories. More than 46% of the errors were "orientation-doubles" observed from subjects using the listing programs. Also, the error having the highest frequency for both model and photograph programs was the "orientation-double". These observations suggest that there is an assignable cause behind both the "orientation-double" part and the listing program. For the "orientation-double" part, the writer would attribute the high number of errors on all types of programs to the fact that the correct response and the incorrect response were different in only one respect. Both had the part on the same pegs and had the same color showing, but the correctness of the response was determined from which peg the color end of the part was placed. Thus, it seems that the less distinct an incorrect response is from the correct response, the more likely a subject will make an incorrect response, given that there is an equal opportunity for both the correct and incorrect responses.

The writer would attribute the high number of "orientation-double" errors from the listing program to the lack of reinforcement. Since the subjects received no feedback from the experimenter, they didn't know whether they were responding correctly or not. Also, they could form an incorrect response, assume it was correct, and then repeat it many times during the experiment. As a clinical observation, the experimenter would say that "negative reinforcement", which is the situation described above, actually happened during the experiment. This lack of reinforcement, as Mr. B. F. Skinner says, is a violation of the basic principles of the learning process. The model and photograph programs offered the subject a more realistic standard to compare his work against than that offered by the listing program. A subject could obtain reinforcement from the photograph and model programs which was not available from the listing program. This agrees with the study of Cross, Noble, and Trumbo (3) in which they found that it was more effective to present a picture of what the operator should duplicate than to give the operator typed directions on what to do.

From previous work (10), their experiment four is the most useful for comparing with this current work. See table 12.

Table 12. Comparison of previous and current experiments.

	Experiment Four		Current		
Task	pegboard		pegboard		
Subjects	students		students		
Average years of school completed by subjects	14.5		13.8		
Layers assembled per medium/subject	48		72		
Media	listing	35mm slides	listing	photos	model
Average time per layer (minutes)	0.72	0.40	0.52	0.36	0.34
Average errors per layer	0.22	0.07	0.14	0.04	0.03
Ratio of times	slides/listing .40/.72=56%		photo/list .36/.52=69%	model/list .34/.52=65%	
Ratio of errors	slides/listing .07/.22=32%		photo/list .04/.14=29%	model/list .03/.14=21%	

Percentage wise, the effect of using the photographs or the model was approximately equal to the effect of using the 35mm color slides when compared against the conventional listing. There doesn't seem to be any reason why a direct comparison of these two experiments is not valid. Thus it seems that the advantage from using slide projection equipment comes from the picture itself and not from the equipment. Color photographs would do just as well and possibly better for presenting a picture to an assembly worker.

CONCLUSIONS

Based upon the data of this experiment, the model programs and the photograph programs were both better than the listing program. The statement is true whether time, errors, or preference is used as the measure of effectiveness. Although the model programs and the photograph programs showed a statistical difference in times but not errors, a clinical observation of the data would indicate that the model program is the better of the two. In situations where it would be practical, models could be used by production assembly workers in assemblying units. Where models would not be practical, perhaps because of their size or the multiplicity of steps, photographs could be used.

There are still many questions that remain unanswered and there is a need for continued research in training industrial workers. How can tasks which would be profitable applications of programmed instruction be identified? At least two experimenters, Goldman and Hart (6), say that the key is in the information content of the task and "information theory" can be used to analyze and compare tasks.

The purpose of the experimenter was to gather evidence to support the hypothesis that color photographs and/or models could be an inexpensive application of programmed instruction to situations which could not economically justify projection equipment. The data collected has sustained this hope. Since much of the work of production is done from information obtained from typewritten listings or blueprints, there is probably a potential savings on many jobs that could be realized by a successful application of programmed instruction to assembly tasks. These applications would not necessarily involve an investment in projection equipment.

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APPENDICES

APPENDIX I

Time Calculations for ANOVA of Table 4

Subjects	Photographs		Model		Listing		Total	
	X	X^2	X	X^2	X	X^2	X	X^2
1.	.295	.087025	.267	.071289	.471	.221841	1.033	1.067
2.	.340	.115600	.345	.119025	.501	.251001	1.186	1.407
3.	.392	.153664	.370	.136900	.559	.312481	1.321	1.745
4.	.478	.228484	.404	.163216	.528	.278784	1.410	1.988
5.	.324	.104976	.319	.101761	.394	.155236	1.037	1.075
6.	.513	.263169	.426	.181476	.877	.769129	1.816	3.298
7.	.338	.114244	.280	.078400	.474	.224676	1.092	1.192
8.	.380	.144400	.374	.139876	.504	.254016	1.258	1.583
9.	.335	.112225	.354	.125316	.522	.272484	1.211	1.467
10.	.428	.183184	.405	.164025	.740	.547600	1.573	2.474
11.	.252	.063504	.265	.070225	.326	.106276	0.843	0.711
12.	.394	.155236	.322	.103684	.498	.248004	1.214	1.474
13.	.323	.104329	.297	.088209	.440	.193600	1.060	1.124
14.	.334	.111556	.332	.110224	.499	.249001	1.165	1.357
15.	.335	.112225	.312	.097344	.432	.186624	1.079	1.164
16.	.344	.118336	.312	.097344	.522	.272484	1.178	1.388
17.	.361	.130321	.356	.126736	.563	.316969	1.280	1.638
18.	.370	.136900	.359	.128881	.580	.336400	1.309	1.713
Totals	6.536	2.439	6.099	2.104	9.430	5.197	22.065	27.865
Average	.363		.339		.524		.409	

X = Average time for 72 layers (36 two-layer tasks) by 1 subject

Sum X^2 = 9.740

Subjects	Sequence	Subject total	Sequence total
	photographs-model-listing		
7		1.092	
13		1.060	
16		1.178	
			3.330
	photographs-listing-model		
1		1.033	
4		1.410	
9		1.211	
			3.654
	model-photographs-listing		
2		1.186	
6		1.816	
11		0.843	
			3.845
	model-listing-photographs		
5		1.037	
8		1.258	
17		1.280	
			3.575
	listing-photographs-model		
3		1.321	
10		1.573	
12		1.214	
			4.108
	listing-model-photographs		
14		1.165	
15		1.079	
18		1.309	
			3.553

$(\text{sum } X)^2/N = (22.065)^2/54 = 486.86/54 = 9.016$ = correction factor

Sequence

$(3.330^2+3.654^2 3.845^2 3.575^2+4.108^2+3.553^2)/9 = 9.056$

$9.056-9.016 = \underline{0.040} = \text{Sum } X^2_S$

Total

$9.740-9.016 = \underline{0.724} = \text{Sum } X^2_T$

Between Individuals

$27.865/3-9.016 = \underline{0.272} = \text{Sum } X^2_{BI}$

Between Experimental Conditions

$(6.536^2+6.099^2+9.430^2)/18 - 9.016 = \underline{0.364} = \text{Sum } X^2_{EC}$

Subjects Within Sequence

Sum X^2_{BI} - Sum X^2_S = 0.272-0.040 = <u>0.232</u> = Sum X^2_{SS}

Residual (experimental error)
0.724-0.272-0.364 = <u>0.088</u>

Source of variation	df	Sum X^2	ms
Subjects	17		
Sequence	5	0.040	.040/5 = 0.008
Subjects x Sequence	12	0.232	.232/12 = 0.0193
Media	2	0.364	.364/2 = 0.182
Error	34	0.088	.088/34 = 0.0026

	F ratios
Sequence	.008/.0193 = 0.4145
Subjects x Sequence	.0193/.0026 = 7.42**
Media	.182/.0026 = 70**

Table Values of F

	.01(**)	.05
F^5_{12}	5.06	3.11
F^{12}_{34}	2.77	2.05
F^2_{34}	5.31	3.28

APPENDIX II

Wilcoxon Signed-Ranks Test On Times

H_o: Photographs = Model

H_A: Photographs > Model

Subject	Photographs	Model	(P-M) di	Rank
1	.295	.267	.028	13.
2	.340	.345	-.005	- 3.
3	.392	.370	.022	9.
4	.478	.404	.074	17.
5	.324	.319	.005	3.
6	.513	.426	.087	18.
7	.338	.280	.058	15.
8	.380	.374	.006	5.
9	.335	.354	-.019	- 8.
10	.428	.405	.023	10.5
11	.252	.265	-.013	- 7.
12	.394	.322	.072	16.
13	.323	.297	.026	12.
14	.334	.332	.002	1.
15	.335	.312	.023	10.5
16	.344	.312	.032	14.
17	.361	.356	.005	3.
18	.370	.359	.011	6.
			T =	-18.

N = 18

Table values

.025	.01	.005
40	33	28

Conclusion: Photographs > Model (.005 level)

H_0: Listing = Photographs

H_1: Listing > Photographs

Subject	Listing	Photographs	(L-P) di	Rank
1	.471	.295	+	
2	.501	.340	+	
3	.559	.392	+	
4	.528	.478	+	
5	.394	.324	+	
6	.877	.513	+	
7	.474	.338	+	
8	.504	.380	+	
9	.522	.335	+	
10	.740	.428	+	
11	.326	.252	+	
12	.498	.394	+	
13	.440	.323	+	
14	.499	.334	+	
15	.432	.335	+	
16	.522	.344	+	
17	.563	.361	+	
18	.580	.370	+	

T = 0

N = 18

Table values

.025	.01	.005
40	33	28

Conclusion: Listing > Photographs (.005 level)

Photographs > Model

Listing > Model

APPENDIX III

Error Calculations for ANOVA of Table 5

Subjects	Photographs X	Photographs X^2	Model X	Model X^2	Listing X	Listing X^2	Total X	Total X^2
1.	2	4	1	1	9	81	12	144
2.	1	1	0	0	0	0	1	1
3.	1	1	1	1	3	9	5	25
4.	1	1	4	16	3	9	8	64
5.	2	4	4	16	32	1024	38	1444
6.	9	81	6	36	34	1156	49	2401
7.	0	0	1	1	7	49	8	64
8.	2	4	0	0	12	144	14	196
9.	2	4	2	4	9	81	13	169
10.	1	1	2	4	8	64	11	121
11.	6	36	1	1	0	0	7	49
12.	8	64	0	0	12	144	20	400
13.	1	1	2	4	2	4	5	25
14.	5	25	3	9	10	100	18	324
15.	1	1	3	9	4	16	8	64
16.	3	9	1	1	19	361	23	529
17.	1	1	0	0	3	9	4	16
18.	5	25	3	9	20	400	28	784
Totals	51	263	34	112	187	3651	272	6820
Average	2.83		1.89		10.39		5.04	

X = Total errors for a medium by 1 subject

Sum X^2 = 4026

Subjects	Sequence	Subject total	Sequence total
	photographs-model-listing		
7		8	
13		5	
16		23	
	photographs-listing-model		36
1		12	
4		8	
9		13	
	model-photographs-listing		33
2		1	
6		49	
11		7	
	model-listing-photographs		57
5		38	
8		14	
17		4	
	listing-photographs-model		56
3		5	
10		11	
12		20	
	listing-model-photographs		36
14		18	
15		8	
18		28	
			54

$(\text{sum } X)^2/N = (272)^2/54 = 1370$ = correction factor

Sequence
$(36^2+33^2+57^2+56^2+36^2+54^2)/9 = 1442.244$

$1442.244-1370 = \underline{72.2} = \text{Sum } X_S^2$

Total
$4026-1370 = \underline{2656} = \text{Sum } X_T^2$

Between Individuals
$6820/3 - 1370 = \underline{903} = \text{Sum } X_{BI}^2$

Between Experimental Conditions
$(51^2+34^2+187^2)/18 = 2151.444$

$2151.444-1370 = \underline{781.4} = \text{Sum } X_{EC}^2$

Subjects Within Sequence

$\text{Sum } X^2_{BI} - \text{Sum } X^2_S = 903 - 72.2 = \underline{830.8} = \text{Sum } X^2_{SS}$

Residual (experimental error)
4026-2273-781.4 = 971.6

Source of variation	df	Sum X^2	ms
Subjects	17		
Sequence	5	72.2	72.2/5 = 14.44
Subjects x Sequence	12	830.8	830.8/12 = 69.23
Media	2	781.4	781.4/2 = 390.70
Error	34	971.6	971.6/34 = 28.58

	F ratios
Sequence	14.44/69.23 = 0.21
Subjects x Sequence	69.23/28.58 = 2.42*
Media	390.70/28.58 = 13.67**

Table Values of F

	.01(**)	.05(*)
F^5_{12}	5.06	3.11
F^{12}_{34}	2.77	2.05
F^2_{34}	5.31	3.28

APPENDIX IV

Wilcoxon Signed-Ranks Test On Errors

H_o: Photographs = Model

H_A: Photographs > Model

Subject	Photographs	Model	(P-M) di	Rank
1	2	1	1	3.5
2	1	0	1	3.5
3	1	1	0	---
4	1	4	-3	-13.5
5	2	4	-2	-9.5
6	9	6	3	13.5
7	0	1	-1	-3.5
8	2	0	2	9.5
9	2	2	0	---
10	1	2	-1	-3.5
11	6	1	5	15.
12	8	0	8	16.
13	1	2	-1	-3.5
14	5	3	2	9.5
15	1	3	-2	-9.5
16	3	1	2	9.5
17	1	0	1	3.5
18	5	3	2	9.5
			T =	-43.

N = 16

Table values

.025	.01	.005
30	24	20

Conclusion: There is no sample evidence against H_o.

H_3: Listing = Photographs
H_4: Listing > Photographs

Subject	Listing	Photographs	(L-P) di	Rank
1	9	2	7	11.5
2	0	1	-1	-1.5
3	3	1	2	4.
4	3	1	2	4.
5	32	2	30	18.
6	34	9	25	17.
7	7	0	7	11.5
8	12	2	10	14.
9	9	2	7	11.5
10	8	1	7	11.5
11	0	6	-6	-9.
12	12	8	4	7.
13	2	1	1	1.5
14	10	5	5	8.
15	4	1	3	6.
16	19	3	16	16.
17	3	1	2	4.
18	20	5	15	15.
			T =	-10.5

N = 18

Table values

.025	.01	.005
40	33	28

Conclusion: Listing > Photographs (.005 level)

H_o: Listing = Model
H_A: Listing > Model

Subject	Listing	Model	(L-M) di	Rank
1	9	1	8	10.
2	0	0	0	---
3	3	1	2	4.
4	3	4	-1	-2.
5	32	4	28	15.5
6	34	6	28	15.5
7	7	1	6	6.5
8	12	0	12	11.5
9	9	2	7	8.5
10	8	2	6	6.5
11	0	1	-1	-2.
12	12	0	12	11.5
13	2	2	0	---
14	10	3	7	8.5
15	4	3	1	2.
16	19	1	18	14.
17	3	0	3	5.
18	20	3	17	13.
			T =	-4.

N = 16

Table values

.025	.01	.005
30	24	20

Conclusion: Listing > Model (.005 level)

PROGRAMED INSTRUCTION FOR A PRODUCTION ASSEMBLY TASK

by

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B. S., Oklahoma State University, 1960

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Recent studies have shown that workers using 35mm color slide programs as an instructional medium for a production assembly task have been able to assemble units faster and more accurately than when conventional typewritten instructions were used. This thesis investigated whether or not the same effect could be obtained without the use of projection equipment.

The tasks used in this experiment were the same as those used in the previous experiments. Three different media were used: color photographs, completed units used as models, and typewritten listings.

Eighteen female subjects assembled 36 units from each of the three media.

The average minutes per layer for the model was 0.339, for the photographs was 0.363, and for the listing was 0.524. The total errors were model: 34, photographs: 51, and listing: 187. There was a significant difference (alpha = 0.01) among the media. The model and the photographs were better than the listing. The model was also faster than the photographs but there was no significant difference in accuracy.