R E P O R T   R E S U M E S

ED 014 895   24   EM 004 090

PRINCIPLES AND PROBLEMS IN THE PREPARATION OF PROGRAMMED LEARNING SEQUENCES.

BY- GLASER, ROBERT
PITTSBURGH UNIV., PA.

REPORT NUMBER CRP-691-4   PUB DATE   SEP 60
EDRS PRICE   MF-$0.25   HC-$1.96   47P.

DESCRIPTORS- *PROGRAMED INSTRUCTION, *PROGRAM DEVELOPMENT, *PROGRAM DESIGN, *PROGRAM CONTENT, *CONCEPTUAL SCHEMES

THIS DOCUMENT DISCUSSES THE FOLLOWING TOPICS IN CONSTRUCTION OF A PROGRAM, AND GIVES EXAMPLES OF RELEVANT SEQUENCES--DEFINING THE FIELD, REINFORCEMENT, GRADUAL PROGRESSION TO ESTABLISH COMPLEX REPERTOIRES, EMITTED BEHAVIOR AND PROMPTING, FADING AND VANISHING, CONFIRMATION AND SCORING, OBSERVING BEHAVIOR, PRACTICE AND REVIEW, UNDERSTANDING AND DISCRIMINATION, EDITING AND REVISION. ALSO DISCUSSED ARE DIFFICULTY LEVEL, PROGRAM TYPES AND "RULEG", ADAPTIVE PROGRAMMING, RESPONSE MODE, SUBJECT MATTER CHARACTERISTICS, INDIVIDUAL DIFFERENCES, MEASURING PROGRAM EFFECTIVENESS, ADMINISTRATIVE CONSIDERATIONS, MACHINES, AND EDUCATIONAL PSYCHOLOGY. (LH)

691 A

[redacted]

PRINCIPLES AND PROBLEMS IN THE PREPARATION OF PROGRAMMED LEARNING SEQUENCES

Robert Glaser

UNIVERSITY OF PITTSBURGH
1787

Department of Psychology
University of Pittsburgh

PRINCIPLES AND PROBLEMS IN THE PREPARATION OF PROGRAMMED LEARNING SEQUENCES

Robert Glaser

Department of Psychology
University of Pittsburgh
Pittsburgh 13, Pennsylvania

September - 1960

A Report Prepared Under Cooperative Research
Project Number 691 (9417)

The United States Office of Education
Department of Health, Education, and Welfare

PREFACE

In the course of completing a recent sourcebook on teaching machines and programmed learning[1] and in the course of recent research I have compiled what appears to me to be the major ideas being expressed in this field. In this paper I should like to set these down, discussing each point briefly and, where appropriate, give or refer to illustrative material. My intent is to present a succinct picture of present notions of programming which will be quite complete in its coverage. The purpose of this paper is such that I have freely used the ideas of others, and as it seemed desirable I have employed words close to theirs where I could only say the same thing less well. However, this has become quite tangled with my own notions and with my organization of the topics discussed; and so I must accept the responsibility for any misinterpretation or lack of clarity. The articles which were my major source documents appear in Parts III and V of the book referred to above. The authors of these articles are: Abram Amsel, John A. Barlow, John W. Blyth, W. J. Carr, J. E. Coulson, J. L. Evans, Charles B. Ferster, Edward B. Fry, Thomas F. Gilbert, Robert Glaser, Wells Hively, James G. Holland, Lloyd E. Homme, A. F. Johnson, Evan R. Keislar, A. A. Lumsdaine, D. J. Mayhew, Susan R. Meyer, Douglas Porter, Sidney L. Pressey, Stanley M. Sapon, H. F. Silberman, and B. F. Skinner.

Robert Glaser

University of Pittsburgh
Pittsburgh 13, Pennsylvania
September, 1960

---

[1] Lumsdaine, A. A., & Glaser, R., Teaching machines and programmed learning, Washington: National Education Association, 1960.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

It is generally recognized now that the success of a teaching machine depends greatly upon the material used in it. The construction of this material is the most difficult and the most crucial task in the development of auto-instructional procedures. The content of this monograph is, therefore, not concerned primarily with hardware or machines. It is rather concerned with the principles, rules, and practices for the construction of programmed learning sequences. It is the development of these techniques which are the heart of the application of learning theory to programmed teaching. The essential task involved is to evoke specific forms of behavior from the student and through appropriate reinforcement bring them under the control of subject matter stimuli. As a student goes through a learning program, certain of his responses must be strengthened and shaped from initial unskilled behavior to subject matter competence. Programming rules are concerned with how one goes about doing this.

Our present knowledge of the learning process points out that through the process of reinforcement new forms of behavior can be created with a great degree of subtlety. The salient feature of this process is making the reinforcement contingent upon the performance of the learner. (Often the word "reward" is loosely used to refer to one class of reinforcing events.) By differentially applying reinforcement to relatively minute behavioral changes, it is possible to progress from the initial behavior of the learner in small steps through the development of more complex behaviors. This progression can take place by small enough steps so that the students progress and motivation is not jeopardized by frequent failures.

Since a great deal of teaching and learning is needed for acquiring complex behavioral repertoires, such as a new language or calculus operations, the number of reinforcements and the subleties of reinforcements required to establish such complicated behavior, overtaxes the skill of the most efficient teacher, especially within the limits of her time and classroom organization. To assist in this complex process, the teacher employs educational materials such as textbooks, workbooks, homework, etc. In all these latter aids the careful monitoring provided by the teacher's skill in shaping behavior is not provided. (Especially in the early stages of learning such guidance is essential.) Perhaps in present-day society we often stray from the real notion of teaching. The teacher, if we think about the early use of individual tutors and the early methods of Socratic teaching, was originally meant to be one who would guide the individual actions of the student. The teaching of champions in sports usually results from the interaction of one man and one coach; the teaching of a skillful scientist often results from the interaction of a graduate student with the individual professor in his laboratory. In the face of large-scale education and with the use of mass educational media, the skillful subleties of the master teacher have been lost or reduced to an average method. It seems, thus, that successive technological advances in education have generally lead to decreased face-to-face contact with the teacher.

Programmed learning may be one answer to preserving the advantages of mass education while at the same time reinstating some of the advantages of individual student-teacher interaction. Educational programming is an attempt to do this. It is concerned with the precise selection and arrangement of educational content based upon what we know about human learning. We know a little and have much to learn. However, we perhaps know enough to make a successful start. The term programming refers to the process of constructing sequences of instructional material in a way that maximizes the rate of acquisition and retention, and enhances the motivation of the student. It is an explicit process, which perhaps an effective teacher does intuitively; the hope is that an effective programmer might someday be able to do this for certain subject matter aspects according to definable rules of programming.

Defining the Field

A first step in programming is defining the field. This means that the programmer must outline precisely the behavior he wants the student to perform at the end of the program and must specify the kinds of stimulus material that the student will have available in the course of this performance. A primary purpose of instruction is to provide the student with a behavioral repertoire called knowledge of the subject matter. If that repertoire is elementary physics then the problem is to take the student there, beginning with whatever initial repertoire he possesses which even vaguely approximates the desired terminal behavior.

As the field is defined, the programmer collects the necessary technical terms, facts, laws, or principles, and illustrative examples. Many illustrative examples are important. One of the essentials of good teaching is to provide the student with a large number of illustrations of an abstraction. It is probably familiarity with a wide range of examples and the ability to generalize to other specific cases that is the operational definition of "understanding." In addition, in starting out to program, the programmer must consider the devices or the teaching techniques by which he can get the initial repertoire to closer and closer approximate the desired terminal repertoire defined as the end-product of learning. Finding the best way to state terminal behavior in order to facilitate program preparation is an important problem in programming instructional material.

Reinforcement

A central process for the acquisition of behavior is reinforcement. Behavior is acquired as a result of a contingent relationship between the response of an organism and the consequent event. In less technical terms, behavior is acquired under conditions in which a response is followed by a subsequent "rewarding condition". In order for these contingencies of reinforcement to be effective, certain conditions must be met. Reinforcement must follow the occurrence of the behavior being taught. If this is not the case, different and, perhaps, unwanted behavior will be learned. In addition, a sufficient number of reinforcements must be given so that the desired behavior is strengthened and its probability of occurrence for a student is high in appropriate situations. As has been said, in progressing from the initial repertoire to the terminal repertoire, the student is reinforced for minute changes in behavior which brings him closer and closer to skilled performance. These minute changes are brought about by successive steps in the program.

In most instructional programs the reinforcing agent for the student is "knowledge of results," that is, knowledge about whether or not the response he performs is the result considered correct. Failure to provide adequate reinforcement and hence failure to strengthen the behavior of the student with respect to the subject matter often results in the student showing a lack of interest. This means that his interest is shifted to other activities for which sufficient reinforcement is provided. A significant aspect of the reinforcing process is that being contingent upon the occurence of a desired response means that it often needs to be immediately contingent, - much more immediate than the usual occurrence in a lecture and in obtaining knowledge of results on a test. In the usual lecture the infrequency of reinforcement often leads to decreased student attention (motivation). In contrast programming can evoke student activity and provide a high rate of reinforcement, in order to maintain student participation.

Gradual Progression to Establish Complex Repertoires

In getting the student from his initial repertoire to the terminal repertoire, it has been indicated that an important principle is that of gradual progression. We do not wait for the student to emit complex behavior in the course of trial and error and then reinforce correct performance. In fact, he may never emit the skillful behavior we require. When developing complex performance we first reinforce any available behavior which is the slightest approximation to the terminal behavior. Later we use this behavior in the next step to reinforce a small change which is in the direction of the terminal repertoire. (The analogy to Skinner's pigeons is an apt one here. If we decide that the terminal repertoire for a pigeon is to turn a circle, face a disc on a wall, peck the disc only if it is lit, and then bend down to pick up food from a food tray - we can not wait for such improbably behavior to occur. When developing such complex performance we may first reinforce such simple behavior as approaching the food tray. Later the pigeon may learn to peck the key only when it is lit. Next he may learn that he must turn around in order to produce the lighted key which he pecks, which in turn produces the food tray which he approaches. This principle of gradual progression runs through many programmed learning sequences.) The program moves in very finely graded steps, working from simple to higher and higher levels of complexity.

The principle of gradual progression serves to make the student correct as often as possible and is also the fastest way to develop a complex repertoire. It is difficult to see how complex behavior can appear except through the specific reinforcement of members of a graded series. It seems that this is an important principle in the rapid creation of new patterns of behavior

TABLE 1

Table 1. A set of frames designed to teach a third or fourth-grade pupil to spell the word manufacture.[1]

1.* Manufacture means to make or build. Chair factories manufacture chairs. Copy the word here:

_ _ _ _ _ _ _ _ _ _ _

2. Part of the word is like part of the word factory. Both parts come from an old word meaning make or build.

manu_ _ _ _ure

3. Part of the word is like part of the word manual. Both parts come from an old word for hand. Many things used to be made by hand.

_ _ _ _facture

4. The same letter goes in both spaces:

m_nuf_cture

5. The same letter goes in both spaces:

man_fact_re

6. Chair factories_ _ _ _ _ _ _ _ _ _ _ chairs.

---

* The word to be learned appears in bold face in frame 1, with an example and a simple definition. The pupil's first task is simply to copy it. When he does so correctly, frame 2 appears. He must now copy selectively: he must identify "fact" as the common part of "manufacture" and "factory". This helps him to spell the word and also to acquire a separable "atomic" verbal operant. In frame 3 another root must be copied selectively from "manual". In frame 4 the pupil must for the first time insert letters without copying. Since he is asked to insert the same letter in two places, a wrong response will be doubly conspicuous, and the chance of failure is thereby minimized. The same principle governs frame 5. In frame 6 the pupil spells the word to complete the sentence used as an example in frame 1. Even a poor student is likely to do this correctly because he has just composed or completed the word five times, has made two important root-responses, and has learned that two letters occur in the word twice. Teaching spelling is mainly a process of shaping complex forms of behavior.

---

[1]Skinner, B. F., "Teaching machines", Science, 128: 969-77, p. 972; 1958.

At the beginning of the gradual progression, instructional stimuli are used to evoke behavior that is already in the repertoire which the student brings to the teaching situation; instruction takes place only when a student proceeds to perform stimulus-response combinations that are different than these. The gradual transfer of behavior to new stimuli is what happens, for example, in teaching the spelling of a word, by first showing it in its entirety and then having the student supply missing parts until he writes the whole word; see Table 1. This is also what happens in learning poetry, arithmetic formulae and so forth; we learn by reading a given sample and then immediately completing the sample when it is presented with parts missing. An important point to make here, that will be emphasized later, is that present notions of programming are such that in proceeding through the gradual progression, little appeal is made to rote memorizing. Skinner points out that in a program the student is expected to arrive at 9 x 7 = 63 not by memorizing it, as we usually memorize poetry, but by utilizing certain principles or interverbal connections that facilitate the acquisition of behavior. The programmer would put into practice in learning 9 x 7 = 63 an obvious and already learned principle as 9 times a number is the same as 10 times a number, minus the number; or another example, the digits in a multiple of 9 add to 9; or another example, 9 times a single digit is a number beginning with one less than the digit, i.e., 9 x 6 is 50 something.

At each step the programmer must ask what behavior must a student have before he can take this step. He must ask what principles or interverbal relationships will facilitate the sequence of steps that form a progression from the initially assumed knowledge to the specified final repertoire. No steps should be encountered before the student can take it with a high probability of success.

Steps

A program, then, consists of steps and, for present purposes little more will be said about this. Among programmers a step is called a frame. Programs teaching school subjects can run to great lengths. Skinner estimates that at five or six frames per word, four grades of spelling may require 25,000 frames. In teaching about one-half of an elementary statistics course the writer has employed 1,374 frames. A recently completed high school physics program uses 3,000 frames to teach six weeks of a course. Specific characteristics of frames such as size, response modes, and other characteristics, have been under discussion and under study by programmers. See Evans, J. L., Glaser, R., & Homme, L., (1959); Coulson, J. E., & Silberman, H. F. (1959; 1960).

Emitted Behavior and Prompting-Making the Desired Behavior More Probable

A student is assumed to possess some initial related behavior in a subject matter before he starts a course. The behavior available must be specified and the programmer can, at the beginning, appeal only to these available responses. How then do we get the student to emit <u>new</u> responses? Before behavior is reinforced it must be emitted, and instructional material must be designed to elicit the correct and appropriate behavior which then can be appropriately reinforced. A major portion of what we now call the rules of programming is concerned with evoking behavior, that is, concerned with techniques for getting the student to emit new or low strength responses with a minimum of errors.

The occurrence of behavior in a program is made more probable if the materials are designed so that each frame makes the correct answer in the next frame more likely. The probability of success is increased (that is, the level of difficulty decreased for an item) by the use of formal hinting and coaching techniques based upon what we know about verbal behavior. For example, a series of items can be designed so that a new word, never before used, is made more likely to occur. The German word "Fabrik" in response to the word factory is made more probable by a preceding item mentioning a colored fabric. Of course, later items would include the word factory where it is not preceded by the word fabric. Ferster and Sapon (as cited in Lumsdaine & Glaser, 1960) in teaching German have suggested that a set of materials could probably be constructed in which each item is designed so that the student will progress from zero knowledge of German to a complicated repertory of the level of a year of college German without ever having made an error. Such an achievement can be made possible by the use of gradual progression, prompting and reinforcement-processes by which the new verbal behavior is created rather than by the traditional processes of memory and recall.

An important factor, then, in working through a program progression, in controlling error, in evoking behavior, and in bringing this behavior under the control of new stimuli, is the use of prompting and cueing techniques. It is obvious that this may be often the stock in trade of a master teacher. However, you must remember that one of the objectives of programming is to make these techniques as explicit and non-intuitive as possible. The notion of prompting is easily seen if we look at a part of the early Skinner physics program in Table 2.

TABLE 2

Table 2. Sample set of frames for automated instruction in high-school physics. Dotted lines show the prompting cues employed. (Words underlined in parentheses are to be supplied by the student)[1]

1. The important parts of a flashlight are the battery and the bulb. When we "turn on" a flashlight, we close a switch which connects the battery with the (<u>bulb</u>).

2. When we turn on a flashlight, an electric current flows through the fine wire in the (<u>bulb</u>) and causes it to grow hot.

3. When the hot wire glows brightly, we say that it gives off or sends out heat and (<u>light</u>).

4. The fine wire in the bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of a(n) (<u>electric</u>) current.

5. When a weak battery produces little current, the fine wire, or (<u>filament</u>), does not get very hot.

6. A filament which is <u>less</u> hot sends out or gives off <u>less</u> light.

7. "Emit" means "send out." The amount of light sent out, or "emitted," by a filament depends on how (<u>hot</u>) the filament is.

8. The higher the temperature of the filament the (<u>brighter</u>, <u>stronger</u>) the light emitted by it.

9. If a flashlight battery is weak, the (<u>filament</u>) in the bulb may still glow, but with only a dull <u>red</u> color.

10. The light from a very hot filament is colored yellow or white. The light from a filament which is not very hot is colored (<u>red</u>).

11. A blacksmith or other metal worker sometimes makes sure that a bar of iron is heated to a "cherry red" before hammering it into shape. He uses the (<u>color</u>) of the light emitted by the bar to tell how hot it is.

12. Both the color and the amount of light depend on the (<u>temperature</u>) of the emitting filament or bar.

---

[1]Skinner, B. F. Material used in a symposium, American Psychological Association, Washington D. C., August 30, 1958.

13. An object which emits light because it is hot is called "incandescent". A flashlight bulb is an incandescent source of (light).

14. A neon tube emits light but remains cool. It is therefore, not an incandescent (source) of light.

15. A candle flame is hot. It is a(n) (incandescent) source of light.

16. The hot wick of a candle gives off small pieces or particles of carbon which burn in the flame. Before or while burning, the hot particles send out, or (emit), light.

17. A long candlewick produces a flame in which oxygen does not reach all the carbon particles. Without oxygen the particles cannot burn. Particles which do not burn rise above the flame as (smoke).

18. We can show that there are particles of carbon in a candle flame, even when it is not smoking, by holding a piece of metal in the flame. The metal cools some of the particles before they burn, and the unburned carbon (particles) collect on the metal as soot.

19. The particles of carbon in soot or smoke no longer emit light because they are (cooler, colder) than when they were in the flame.

20. The reddish part of a candle flame has the same color as the filament in a flashlight with a weak battery. We might guess that the yellow or white parts of a candle falme are (hotter) than the reddish part.

21. "Putting out" an incandescent electric light means turning off the current so that the filament grows too (cold, cool) to emit light.

Let us look at some examples of prompts. First, a class of prompts that are called thematic prompts. Some examples are presented in Table 3. A second class of prompts are called formal prompts and involve echoic and textual behavior such as shown in Table 4. Some additional examples of textual or semantic cueing have been listed by Lumsdaine in Table 5. Prompting occurs within frames but also as has been indicated, in the physics program in Table 2, between frames; in the latter case adjacent steps are similar enough so that one frame sets up a response to another. Teaching machines designers point out that the use of teaching-machine hardware is probably the best way to insure independent exposure of successive frames. An interesting study of prompting has been made by S. R. Meyer (As cited in Lumsdaine and Glaser, 1960) in working with a high school vocabulary program. A brief example of her very interesting program can be found in Table 6. The prompts employed in the program Meyer describes as follows:

> Copying in a simple item.
>
> Assuming no knowledge of the prefix or its definition, a standard format was adopted. The first example of such an item in Lesson 8 read: "The prefix trans- means 'across' or 'over' (from one place to another). A transatlantic flight goes ________ the Atlantic Ocean." In each item of this type the prefix was underlined, the definition was in quotation marks, and the student was required to copy one or the other in relation to a fairly common word. Other "simple" copying items specified the prefix to be used, leaving the student to spell it correctly. . .
>
> Copying in a complex item.
>
> "Complex" items were of three types: (a) two prefixes were given, and the student had to choose which answer belonged in which blank; (b) an example was given from which to construct a new example; (c) the answer was available in the text but was not isolated by underlining and quotation marks as it was in the "simple" copying items. . . An illustration of copying-from-example is the following item from Lesson 14: "A flame emits or sends ______ light.

TABLE 3

Table 3. Thematic prompts.[1]

a. "Lead-ins." Common knowledge or phrases with high association value for the desired word can sometimes be used. To the frame: "A doctor taps your knee (patellar tendon) with a rubber hammer to test your _____," 174 out of 182 students said "reflexes." To the following frame: "If your reflexes are normal you _____ to the tap on the knee jerk," 107 out of 182 said "respond" and 72 said "react"--both responses being accepted as correct by the programmer. These already known terms could then be preserved and supplemented as part of a technical repertoire.

b. Indicating categories, sublanguages, or syntax. A technical or lay term may be specifically asked for. That a response is to be a color-word is indicated in the sentence "Roses are colored _____," although "Roses are _____" would collect responses like "flowers, beautiful," etc. Whether a response is to be a verb, noun, adjective, or adverb can sometimes be determined by supplying endings, such as -ly, or -ed.

c. Useful Category. "Opposites" is an example. To the item: "Reinforcement which consists of presenting stimuli (e.g., food or water) is called positive reinforcement; reinforcement which consists of terminating stimuli (e.g., loud noises or painful stimuli) is called _____ reinforcement," 173 out of 180 students said "negative." The result would be further assured by underlining "presenting," "terminating," and "positive" and adding a phrase like "on the other hand," after the semicolon.

d. High-association words or common phrases. To the item: "A reward simply makes it more _____ that an animal will behave in the same way again," 32 out of 95 students said "probable," 43 "likely," and 18 "certain," all of which were acceptable, the lapse in grammar in the last case being forgiven.

e. Eliminating undesired alternative responses. The item: "Coins are conditioned _____ reinforcers" will bring out the desired response "generalized" more often than: "Coins are _____ reinforcers" which will get many instances of "conditioned." Another solution is to have the student supply both alternatives, frequently with some indication of category or sublanguage. Thus an item might conclude: ...." is called _____ or, in technical terms, _____."

---

[1]Skinner, B. F. The use of teaching machines in college instruction. Final report to the Fund for the Advancement of Education, August 15, 1958, 39-40.

TABLE 4

Table 4. Echoic and textual behavior and formal prompts.[1]

a. Panels. An effective way of evoking new terms is to use printed material which remains before the student while he works through a disk or tape. Early frames guide him through careful textual behavior. This distinction between this and reading a text for memorization is that comprehensive reading is not assumed but rather forced by the frames which carry him through all the points on the panel. The panel should include nothing which is not treated by the frames, because it should be as short as possible. The labor of searching the panel should be kept to a minimum. Reference letters or numbers are useful for this purpose in referring the student to particular parts of the panel. Subsequent tapes or disks should cover the same concepts and principles without the panel. These should contain new frames rather than repetitions of previous frames.

b. Use of new words in a series of frames. Correct responses in a short series can be made to depend on careful observation of a new word. In the last frame in the series the student must write the word.

c. Definitions and examples. These generate sentences easily completed. In an experiment described in more detail, 95 out of 95 students answered "reinforce" to the frame: "A technical word for reward is reinforcement. To reward an organism with food is to ______ it with food." To the next frame: "Technically speaking, a thirsty organism can be ______ with water," 87 out of 95 answered "reinforced," 7 answered "rewarded," 1 "conditioned".

d. Explicit formal prompts. A response of low strength can be made more probable by giving its beginning or ending or selected letters. Indicating the number of letters is not very effective as a prompt, but permits the student to discard wrong responses.

e. Rhyming as a formal prompt. A technique suitable for the young:

"Nine times seven and just one more
Is eight times eight or ______."

[1]Skinner, B. F. The use of teaching machines in college instruction. Final report to the Fund for the Advancement of Education, August 15, 1958, 38-39.

TABLE 5

Table 5. Some contextual or semantic cueing techniques: Prompting techniques used within frames of teaching-machine programs.[1]

(1) Partial presentation of a word, with omitted letters to be filled in--letters present varying from nearly all present (maximal cueing) initially, to all or nearly all absent (minimal cueing) terminally.

(2) Similarity of ideas, calling for a response that is provided in a similar context--e.g.

Just as smoke rises, warm air will also _____.

(3) Similarity of grammatical construction--e.g.,

The higher the temperature, the faster the molecules move; the lower the temperature, the _____ they move.

(4) Constriction of the range of response by grammatical construction--e.g.,

The throttle is advanced just _____ the ignition is turned on. (Requiring a temporal word such as before or after.)

(5) Similarity of word roots with similar meaning used in a preceding "frame" or earlier part of the same frame--e.g.,

A candle flame is hot; it is a(n) _____ source of light. (Sesired response: "incandescent")

(6) Obvious transpositions

Gross profit less overhead equals net profit; so to get net profit you subtract _____ from _____.

---

[1]Lumsdaine, A. A., The development of teaching machines and programmed self-instruction. New teaching aids for the American classroom. Stanford University, Calif.; The Institute for Communication Research, 1960, pp. 136-73.

TABLE 6

Table 6. Part of a junior high-school vocabulary program.[1]

Sentence to be completed	Word to be supplied
1. The prefix circum (think of "circle") means "around". The circumference of a circle goes _____ the outside.	around
2. Circumstances are events going on _____ you when something happens.	around
3. A person who sails around the world _____navigates the world.	circum
4. A cautious person looks around carefully before doing something; he is _____spect.	circum
5. Which of these airplanes would fly furthest? _____. Least? _____. a) interstate b) circumglobal c) transcontinental	b, a

[1]Meyer, S. R. "Report on the initial test of a junior high-school vocabulary program." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 229-46.

> A person who has left his native country is an _______ migrant." The item was in a lesson dealing with spelling similarities of ex- and dis-, which were explained on a panel. . .
>
> Copying from a panel.
>
> Eight items in the program required a specific word from the panel accompanying the lesson. The sentence containing the blank was followed in each case by "(See panel.)". The panels generally contained several "rules" or a paragraph of explanatory material. . . Items of this type were classed as "complex" copying because a search of a large amount of material was required. . .
>
> Indications of the number of letters or words to be supplied
>
> An example is as follows: "The front part of something is called the ___ ___ ___ ___ rior. . . . The middle part (in between) is called the ___ ___ ___ ___ ___ ior." The items constituted a review of super-, inter-, post-, and ex- in the middle of the lesson on ante-. . .
>
> The root as a formal prompt.
>
> Giving the second half of a word limited the number of choices for the first half that a reader of English would recognize as correct. In order to recognize the correctness, of course, the student must have the whole word in his vocabulary. If the completed word is not in his vocabulary, the root cannot act as a prompt. Using the Thorndike word frequencies as a measure, the roots supplied for completion were divided into three groups: (a) those which, with the correct prefix, produced an AA or A word (first- to third-grade vocabulary); (b) those which produced a word with a frequency between A and 20 (fourth-grade vocabulary); and (c) those which were ranked below 6 (high-school vacabulary and beyond). . .
>
> Inter-item prompts.
>
> The prefixes were typically introduced in an item requiring the student to copy either the prefix or the root (the "simple copying" item discussed above). The item immediately following it required either the same part of the word as before or the noncopied part. In both cases the student had presumably just read both, although he had copied only one. . .

An additional form of cueing of interest and presently being studied by Lumsdaine consists of giving the learner a partial or faint representation of the response cue which directly but incompletely suggests the desired response. Such variations in cue strength could be performed by variations in visual noise, brightness, and legibility. An example of this is given in Table 7.

An interesting example of prompting is one given by Skinner (as cited in Galanter, 1959):

> In the simplest case two verbal stimuli are presented together and responses evoked for some reason or other. It is more effective to connect the stimuli with an explicit defining autoclitic, such as "X means X". One verbal stimulus sets off in apposition to another, or after the word "or", in an implied definition. The result is not the mere learning of a vocabulary. Compare, e.g., a set of frames designed to acquaint the student with the Greek prefixes for number. The set might be used, for example, in teaching the systematic vocabulary or chemistry. The student is to acquire the correct use of mono, di, tri, tetra, penta, etc., under the control of numerical aspects of verbal and non-verbal stimuli--e.g., pictured polygons, or the subscripts in chemical notations. Existing connections in the student's repertoire can be exploited, going first from Greek to English, as in Decalogue is another name for the _ _ _ _ Commandments," or "A monocle is a lens for use in only _ _ _ _ eye." The student can then complete familiar and later unfamiliar expressions by substituting the Greek prefixes (which may be present on a panel during early stages) as in "The five-sided building in Washington used by the Army is called the _ _ _ _ _ _ _ gon," or "People who make a practice of having only one wife or husband are called _ _ _ _ _ _ _ _ _ _ gamous," or "A line of poetry having six feet is called _ _ _ _ _ _ meter." From such general material the student can then be transferred to a specific application--as in being asked to compose the technical names for chemical compounds indicated with symbols ("CF_4 is carbon _ _ _ _ _ _ _ _ _ _ flouride") or to write the symbols for compounds named, "Osmium octafluoride is written _ _ _ _ _ _ _ _ _ _." The ultimate goal is to permit the student to move quickly from a numerical aspect of a nonverbal stimulus or from a numerical verbal stimulus to a verbal response containing the Greek prefix.

It is the case, then, that techniques for getting out new or low strength responses with a minimum of errors, i.e., a variety of methods which need to be made explicit, include such things as: (a) the use of new words in a series of frames before requiring the student to use them

TABLE 7

Table 7. One form of a method of prompting depending on physical variations of visual cues.[1]

(a) Kelvin is a ~~scale~~ ~~of~~ ~~temperature~~.

(b) Kelvin is a ~~s~~ca~~le~~ ~~o~~f ~~tem~~p~~er~~a~~ture~~.

(c) Kelvin is a sca~~le~~ ~~o~~f ~~te~~mp~~er~~at~~u~~r~~e~~.

(e) Kelvin is a sca~~le~~ of ~~t~~emp~~er~~a~~t~~ur~~e~~.

---

[1]Klaus, D., & Lumsdaine, A. A. Self-instructional supplements for a televised physics course. Pittsburgh: American Institute for Research, 1959, p. 27.

(b) moving from definitions to examples within a single frame, (c) "leading-in" from an assumed common knowledge, (d) indicating relevant categories to which the response term belongs, (e) using high-association words or common phrases, (f) eliminating undesired alternative responses by careful phrasing of the frames. Some programmers, for example, have employed the use of "panels", i.e., short passages of printed material, graphs, etc., in front of the student while he works on a particular set of frames.

Fading and Vanishing

Thus far it has been indicated that programming techniques utilize (1) the principle of reinforcement, (2) the principle of progression, and (3) the principle of prompting. The next one we come to is (4) the principle of fading or vanishing. This principle involves the gradual removal of prompts so that by the time the student has completed the lesson, he is responding only to the stimulus material which he will actually have available when he performs the "real" task. He is on his own, so to speak, and learning crutches have been eliminated. Fading then can be defined as the gradual withdrawal of stimulus support. The systematic progression of programmed learning is well set up to accomplish this. It is always to be kept in mind that these principles are quite in contrast to "rote learning or drill". In rote learning, many wrong responses are permitted to occur, and the student eventually learns to develop his own prompts often to a relatively unrelated series of stimuli. Programmed learning, on the other hand, is designed to take advantage of the inherent organization of the subject matter and of the behavior of the subject in relation to the subject matter in shaping up the student's learning.

To illustrate the technique of fading, let us look at how a student can learn to recite a poem in a programmed learning sequence. (Skinner, 1958.) "The student must read the line 'meaningfully' and supply the missing letters. The second, third, and fourth frames present succeeding lines in the same way. In the fifth frame the first line reappears with other letters also missing. Since the student has recently read the line, he can complete it correctly. He does the same for the second, third, and fourth lines. Subsequent frames are increasingly incomplete, and eventually--say, after 20 or 24 frames--the student reproduces all four lines without external help, and quite possibly without having made a wrong response. The technique is similar to that used in teaching spelling: Responses are first controlled by a text, but this is slowly reduced (colloquially, 'vanished') until the response can be emitted without a text, each member in a series of responses being now under the 'intraverbal' control of other members."

As another illustration consider instructing a student to identify maps, anatomical drawing, etc., we can present a non-verbal stimulus, i.e., a model or picture, along with the text or verbal response. That is, a name appears on the outline of a country or a part of an anatomical drawing. This juxtaposition provides a stimulus and response for the student. For efficient instruction, he must emit some behavior and can do this by comparing pictures, describing details of the pictures, and so forth. The text is then vanished at a suitable rate so that eventally the student can verbally name the object in response to the non-verbal stimulus, and can talk about relations among cities and countries without any map at all. (Holland, J. G. as cited in Lumsdaine and Glaser, 1960).

Fading and vanishing, then, is another major programming principle. It refers to the gradual withdrawal of information so that the student must more and more rely on himself to the extent that this is called for in criterion behavior specified as the objective of instruction. An example from an algebra and a spelling program are given in Table 8. (For illustrating the point, the frames in these tables progress more rapidly than might be the case in an actual program presented to the student.) Another interesting example of fading has been given by Gilbert (1959) in Table 9. Here he employs mediating associations which are eventually faded. A program dealing with the translating into numbers the color bands on a resistor is also shown in this table. At the present time a number of programmed learning investigators are concerned with a number of questions about fading--how gradual or rapid it should be, how repetitive it should be, and so forth.

Confirmation and Scoring

As indicated, an important aspect of programmed learning is the fact that the program has in it some confirming mechanism by means of which the student receives information as to the correctness of his response. It is generally assumed that this confirmation can provide appropriate reinforcement. Without enough such confirmation the students tend to lose the point of a long development and also often fail to respond to frames at all; they may omit responses, misplace responses, etc., (Meyer, S. R. as cited in Lumsdaine and Glaser, 1960). One aspect of presenting the correct answer in a gradual progression of frames is that its

TABLE 8

Table 8. An example from an algebra program.[1]

ITEM	ANSWER
14. The commutative law for addition states that a + b = b + ____.	a
15. The commutative law for addition states that a + b is equal to ____ + ____.	b + a
16. The commutative law for addition states that ____.	a + b is equal to b + a

Another example for a sixth grade spelling program.

ITEM	ANSWER
41. Circle the word that may mean <u>to be in pain</u>: suffer, swell, improve, drug, fountain.	suffer
44. Write in the missing letters. They are both the same: I hope Queenie does not have to su_ _ er.	suffer
47. Write the missing letters: I hope Queenie does not have to s_f_ _r.	suffer
49. Write the missing letters. I hope Queenie does not have to s_ _ _ _r.	suffer
51. Write the missing letters. I hope Queenie does not have to s_ _ _ _ _.	suffer

[1]Gilbert, T. F. "An early approximation to principles of programming continuous discourse, self-instructional materials." <u>Psychological problems and research methods in mathematics training</u>. (Edited by R. L. Feierabend and P. H. DuBois.) Cooperative Research Project No. 642, June 1959. (Mimeo.)

TABLE 9

Table 9. The color Code for Resistors in which a mediating association is presented for each color-number pair.[1]

ITEM	ANSWER
1. A black band on a resistor stand for 0: 0, black, nothingness. The black band stands for _____.	0
2. A brown band on a resistor stand for the number 1: 1, brown, penny. A black band stands for _____.	0
3. A number 1 is represented by a (a)_____ band, a number 0 is represented by a (b)_____ band.	(a) brown (b) black

[1] Gilbert, T. F. "An early approximation to principles of programming continuous discourse, self-instructional materials." Psychological problems and research methods in mathematics training. (Edited by R. L. Feierabend and P. H. DuBois.) Cooperative Research Project No. 624, June 1959. (Mimeo.)

primary function may be to produce the motivation to work carefully since the student works to come up with the correct answer at each step. Confirmation of the correct response can occur in several ways. For example, (a) it can be displayed as soon as the student makes a response, or (b) it can be exposed only if the student's response is correct; if it is wrong, he is prevented from going on until he tries again. Under discussion among programmed learning investigators are the characteristics of procedures for confirmation of the correct response.

The further problem arises of who shall score the student's response. In most programs the student makes a response and then upon receiving the confirmation makes his own judgment of whether he is right or wrong by comparing his response with the correct response shown in the program. A study by Meyer (as cited in Lumsdaine and Glaser, 1960) has investigated the accuracy with which students perform this task and conditions under which they are more or less self critical. It is also possible for a machine to be so automated so that it senses and scores the correctness of a response. L. B. Wyckoff has built a prototype of a simple machine of this kind. The characteristics of judgmental versus automatic scoring is a question for study.

Observing Behavior

It has been indicated that immediate confirmation "encourages a more careful reading of the programmed material than is the case in studying a text where the consequences of attention or inattention are so long deferred that they have little effect on reading skills." (Skinner, 1958) Observing or attending behavior is efficiently shaped by the contigencies of the program. When immediate reinforcement is forthcoming it appears that a student will be more likely to learn how to concentrate on specific features of a presentation. This is to say that the constant application to the subject matter which a program demands may not permit the development of competing habits of susceptability to distraction; less controlled methods of teaching, however, may allow such behavior to occur more frequently.

Practice and Review

In the course of a program progression, the programmer must build in the amount of review and repetition necessary to maintain previous learning and to maintain already learned concepts which need to be strengthened and utilized in further learning. Sufficient practice and over-learning is necessary so that early material is thoroughly mastered before or while new material is introduced. In certain program sequences the steps may become larger and larger as the student learns more and more. Also with fading and with the drop-out of lessons already mastered, a systematic transition can be made from old to new concepts with a sufficient amount of review and repetition. Concepts not otherwise involved in a particular sequence of items can be reviewed periodically. Programmers use the word "seeding" and talk about the seeding of review materials at various points in a program in order to insure the maintenance of learning. Many problems still remain to be answered with respect to the characteristics and scheduling of review. In general, however, abundant practice is the rule and is obviously better than too few repetitions.

One of the characteristics of repetition is its deadly and aversive redundancy. With this in mind, one of the principles of programming is to continously vary the context of repetition. In doing this the student receives new information, he learns to make finer discriminations, and learns to apply what he has learned to a wide variety of situations. This varying of stimulus context makes repetition less aversive especially to the bright student. It is further to be pointed out that repetition which involves the development of new discriminations and the introduction of new situations so that the student's breadth of learning is spread and enriched, is probably what we mean by "understanding" a subject matter.

Understanding and Discrimination

A major principle in programmed learning, following from the previous paragraph, is that after certain materials have been mastered the student should use them in varied contexts. For example, a student can not be presumed to have a thorough mastery of the concept "noun" until he has worked with material that requires him to distinguish between nouns and verbs. This kind of descrimination is related to concept formation. Individuals build up concepts and abstractions on the basis of discrimination training and generalization. They learn to discriminate between the members of two classes, like animate and inanimate objects, and learn to generalize the concept animate to all members of one class. The progression in a programmed learning sequence can provide a well-organized sequence of examples by which the student is lead to develop abstractions and rather complicated concepts. Examples of this are programs presented by Holland (as cited in Lumsdaine and Glaser, 1960) and by Blyth (as cited in Lumsdaine and Glaser, 1960)

The important goal is to enrich the student's understanding by making him permute and recombine the elements of his behavior. (Skinner, as cited in Galanter, 1959) At the extreme of stimulus and response variation, the programmer is really not concerned with the student's response to any one situation. He is only concerned with this as a sample of an abstraction. We wish the student to acquire not a uniform and explicit verbal repertoire about the concept but rather acquire a repertoire which is applicable in a variety of situations so that he can use the concept to solve problems, describe it to others, modify it for specific purposes, build a model of it, and so forth. When he can do this we say he understands a concept. In the course of programmed learning the characteristics of this response are learned not because the same form of response recurrs again and again, but rather because it grows under programmed variation. (Skinner, as cited in Galanter, 1959).

Editing and Revision

A most important aspect of a programmed learning sequence is that it provides constant feedback about its effectiveness. If a student does not learn we say that there must be something wrong with the program and we attempt to modify it. The editing and revision of instructional material now becomes a very empirical matter in which we learn from the behavior of the learner. Each successive revision of a programmed learning sequence helps to insure that the student's performance is brought closer and closer to the defined terminal behavior, i.e., the educational objectives of the program. Examples of program revision have been reported by Holland (as cited in Lumsdaine and Glaser, 1960) and Meyer (as cited in Lumsdaine and Glaser, 1960). The detailed analysis of the students interaction with the program can teach us much about learning and teaching.

Weaning

An objective to programmed learning, especially when programs are put into machines is that the student will come to depend on the machine and will be less able than ever to cope with the existing real world containing lectures, textbooks, and films. However, "All good teachers must 'wean' their students, and the program and the machine is no exception. The better the teacher, the more explicit must the weaning process be" (Skinner, 1958). The final stages of the program must be so designed to free the student from his dependence on it. In his very early work Porter (as cited in Galanter, 1959) points out that with his spelling program the students do not become dependent on the machine but that the effect is just the opposite. His evidence indicates that young children taught spelling by a programmed learning sequence tend to get rid of poor study habits, such as not reading instructions, or only partially looking to see whether what they have written is correct. These gains in study skills may certainly facilitate weaning from the apparent automaticity of programmed learning.

SOME FURTHER CONSIDERATIONS

Difficulty Level

The question often arises concerning the difficulty level of the frame in a program. It is obvious that the material to which the student responds must allow only infrequent errors while at the same time advancing toward new knowledge. This seems to suggest a fine line between an "easy" and "hard" level of difficulty which a frame must involve. We need to study more about this and about what difficulty levels frames should be "peaked", to borrow a psychometric or an electronic term. Especially we need to consider the development of techniques of frame construction which permit differential responding and appropriate reinforcement for a wide range of student aptitude; work of this kind is in progress by programming researchers. As a result of this work it should be possible to prepare "double-track" programs which are challenging to both bright and less bright students. Such programs would permit the student to call forth prompts as he needs them in order to make an adequate response. (Such a technique is being studied in the work by J. B. Carroll, A. A. Lumsdaine, and B. F. Skinner in their present work on programming.)

Related to difficulty level is the fact that it is often thought that education must be difficult in order to be effective. This, however, may not be the case. The teacher turned programmer may be surprised when he finds that he is writing items that give the point away. It seems, however, that programmed learning with appropriate prompting can give the point away as a means of effective teaching. (Skinner, 1958)

Inductive, Deductive Programs, and "Ruleg"

A question that arises in programming is related to induction and deduction. What is involved here are two methods of progression: (1) shall a student be taken through various instances so that he comes to learn a concept as it is developed, or (2) should the concept be verbally stated, then various instances given to elaborate it? Programs have been built both ways and more experience is needed with various subject matters. An illustration of a programming procedure which is oriented about the progression from concepts through examples has been called the Rule-Example System or the Ruleg System and is described in a separate report (Evans, J. L., Homme, L. E., and Glaser R., 1960).

Adaptive Programming

Of considerable interest in programmed learning is the notion that programs can be constructed in linear fashion or so constructed that they are "adaptive". At the present time the term "adaptive" generally refers to the use of a branching procedure which involves shifting of the difficulty of the material presented to a lower level when the student has difficulty responding to a particular sequence or shifting to a higher level when the student is responding very rapidly and quite correctly. The characteristics of adaptive procedures, the way in which certain adaptive procedures facilitate learning, the necessity for adaptive measures, and the use of complex computing mechanisms for adaptive programming are all of high interest at the present time. (Pask, as cited in Lumsdaine and Glaser, 1960), (Crowder, as cited in Lumsdaine and Glaser, 1960), and (Coulson & Silberman, as cited in Lumsdaine and Glaser, 1960). Adaptive programming involves much complication as compared to linear programming, and its utility in terms of efficient teaching practice and effective learning must be carefully investigated. Research should study the influence of various techniques and also compare them with minimal branching procedures.

Response Mode

Just how does the student respond to the frames in the programmed learning sequence. The characteristics of the students' response has implications for just how the program is physically constructed and just how the machine is designed. A program can require that the student supply multiple-choice answers, or write-in (completion) answers, or implicit responses where the student punches an entire paragraph into the machine, or whether he might use some sort of a key or typewriter arrangement and respond letter by letter and be informed of his correctness letter by letter or word by word. It is perhaps for this reason that response mode has received attention by investigators. (It has also perhaps received undue attention because of the difference between the Pressey and the Skinner procedures.) These different response modes have significant implications for machine design and program construction. The basic concern, of course, is the determination of the kind of responses that are required for the learning of particular subject matters which result in the most efficient learning and the most effective attainment of educational goals involving understanding, transfer of training and so forth. Just how specific are the effects of particular modes of responding by the learner? Some studies (Evans, 1960) indicate that a specific kind of responding has effects on immediate tests but on retention tests the effects seem to dissipate. It is also possible that the high-strength verbal behavior used in many programs is so generalizable that the student can transfer readily from response mode to response mode; and thus, the mode of responding may not be a significant variable in many kinds of learning. Further, it is also likely that the effectiveness of response modes changes with educational level of the student and from earlier learning in a particular subject matter to a later learning requiring, complex responding. Such questions as these need to be raised in future research.

Subject matter characteristics

A consideration in programming is the interaction of the characteristics of different subject matters with the characteristics of the programmed learning sequences required to teach them. Certain subject matters like mathematics and some of the sciences seem well organized for the preparation of programmed learning sequences; other subject matters such as history, social studies, and others have characteristics of programmed learning which can make their sequences quite different. The organization of subject mattors and the structure of a body of knowledge as it interacts with teaching of that knowledge is an important ramification involved here. The notion has been expressed by programmers that interaction between the structure of the teaching process through attempts at programmed learning and the structure of knowledge of a particular subject matter may well result in revised knowledge structures. It may be that subject matters which in the course of their development have been organized by some scheme or other depending upon the investigation of a particular man or group of men may now be reorganized on the basis of how well this organization facilitates teaching and how well this new structure permits the fostering of creative activity. This certainly can have far-reaching consequences.

Individual Differences

Students in a school system enter with different backgrounds and with various behavioral histories, and the question arises concerning the influence of these differences upon programmed learning procedures. It is probable that the effectiveness of certain kinds of learning sequences will interact with the existing behavioral repertoire (achievement level and aptitude patterns) of the student, and it is of interest to investigate the differential effectiveness of various types of programmed sequences with students having different characteristics. However, with the use of programmed learning the effect of student heterogeneity on teaching practices should change. Student differences which show up at the beginning of a course of instruction can be reduced by preparatory programs which bring the students up to the achievement level required to enter the course. Further, since a student can work individually on certain subjects, the classroom as a teaching entity can be appropriately modified.

Measuring Program Effectiveness

Programs need to be evaluated by means of carefully developed achievement tests which measure the defined terminal behavior in terms of stimulus material generally agreed upon as being relevant to this task and having adequate content validity. However, the knowledge achieved by the student is only one aspect of the assessment of the effectiveness of a programmed learning sequence. Efficiency of teaching is another aspect. A student in a lecture and a student working on a teaching machine may learn the same thing but using the machine may teach him in half the time. Preliminary study seems to indicate that when traditional teaching methods are compared with programmed learning procedures, good students learn equally well under both conditions; however, they learn in less time with a program and consequently can cover more ground in a subject matter. Poorer students, on the other hand, do obtain higher test scores after programmed learning as compared with traditional procedures. This would suggest that some time/quality measure be employed to evaluate the effectiveness of programmed learning.

Administrative Considerations

A miscellany of things can be included here. For example: What is the length of the learning session and the amount of material to be covered in a session. What sort of time limits are imposed upon self-instruction in the administrative setting of a high-school or college? How will programs have to be adapted to existing education and to what extent will existing education have to change under the influence of programmed learning notions? Some people venture to predict that the physical construction of buildings will change with much less space given to mass meeting rooms and much more space for small group presentations and places where students can go for individual self instruction. Another problem involved is the actual construction of programs. Will learning programs be developed by specific school systems? Will there be many programs in arithmetic like there are many textbooks in arithmetic? The development of programs and teaching machines is a much more sizeable expenditure than the development of textbooks, and it would seem that production sources might be less wide spread. Administrative ramifications such as mentioned in this paragraph are further discussed by Finn (as cited in Lumsdaine and Glaser, 1960), Carpenter (1960), and in the Conculding Remarks of Lumsdaine and Glaser (1960).

Machines

Inseparable from all that has been said so far, and as has been indicated, are the specific characteristics and design of teaching machines. Just what will be their characteristics, how will they be designed, what will they need to be designed to accomplish the purposes, etc.? All this is, of course, highly interdependent with other characteristics of programmed learning and many questions arise. We must decide what we want the machine to do and we must ask the engineer what the machine can do. What should be the display characteristics of the machine, and how should it present programmed materials? Should the material automatically advance, or should the student call for the next material, should he push it through with a pencil, should he press a button, should the material be paced and come up without the student calling for the next frame, etc. How shall the machine receive the responses of the student? Should the machine receive handwritten responses by the student, should the machine receive typed responses by the student, should the machine make provisions so that the student can check off certain multiple-choice answers? These aspects have been indicated previously, but all are involved in determining the characteristics of a particular machine.

Further, how should the machine inform the student of the correctness of a response; should it inform him after every response, every five responses, after part of a response, etc.? The question of sense modalities comes in here. Most present-day machines use visual displays and are set up to receive written responses. Language laboratory people are concerned now with machines that can receive auditory responses and also present auditory displays. Particular techniques of prompting are also involved in a machine design. If prompting is verbal or semantic then the printed program is adequate. If prompting techniques employ physical variations such as the brightness of stimuli, etc., then additional factors are required in machine construction. A host of questions are involved here which need to be answered before any finally designed machines are developed. At the present time, we can develop the best machines we know how, and it seems likely that they will be effective in accomplishing their ends; however, continued development certainly is the keynote. In addition, machines need to be built for research as well as teaching. It is probably well to build all machines with a research capability. This means the machine will have some extra instrumentation to keep careful recordings of how the student learns and the characteristics of his particular responses. This information can be sent to appropriate research bureaus for careful analysis or be utilized for briefing teachers on how students have learned the subject material under consideration.

Educational Psychology

Perhaps the most tremendous impact of the programmed learning movement is the fact that the notions involved permit us to consider very careful control of the behavior of the learner. Along with this careful control comes the need for knowledge of specific techniques for the guidance of learning. If instrumentation is developed for this purpose then the information obtained from its use can be used for the investigation of the learning process and for specification of different techniques of educational technology. Involved in this is the development of a theory of the instructional process and of a specifiable teaching technology. It is conceivable that learning programs can be developed in certain subject matters in which the characteristics of the particular frames in a sequence can be carefully identified as to their educative and psychological characteristics. Once we develop extensive teaching sequences in which we can identify the pedagogical functions of each of the characteristics of the sequence, we have gone a long way toward specifying the characteristics of the teaching process. This process can then be translated into a teaching technology which can be taught in colleges of education. In combination with this technology each teacher could also bring to bear the particular attractiveness of his own artful and creative behavior.

REFERENCES

1. Blyth, John W. "Teaching machines and human beings." In Lumsdaine, A. A. & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 401-15.

2. Carpenter, F. "The teaching machine and its educational significance." Paper read at the Twelfth Annual Meeting of the American Association of Colleges for Teacher Education, Chicago, Ill., February 1960.

3. Coulson, J. E., & Silberman, H. F. "Effects of three variables in a teaching machine." Journal of educational psychology, 51: 3, 135-43; 1960.

4. Coulson, J. E., & Silberman, H. F. "Results of an initial experiment in automated teaching." In Lumsdaine, A. A. & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 452-68.

5. Crowder, N. A. "Automatic tutoring by means of intrinsic programming." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 286-98.

6. Evans, J. L. An investigation of "teaching machine" variables using learning programs in symbolic logic. A report prepared under Co-operative Research Program of the United States Office of Education at the Department of Psychology, University of Pittsburgh. August 1960.

7. Evans, J. L., Glaser, R., & Homme, L. E. "A preliminary investigation of variation in the properties of verbal learning sequences of the 'teaching machine' type." In Lumsdaine, A. A. & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 446-51.

8. Evans, J. L., Homme, L. E., & Glaser, R. The Ruleg (Rule-Example) System for the construction of learning programs. A report prepared under the Cooperative Research Program of The United States Office of Education at the Department of Psychology, University of Pittsburgh. August 1960.

9. Ferster, C. D., & Sapon, S. M. "An application of recent development in psychology to the teaching of German." In Lumsdaine, A. A. & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 173-85.

10. Finn, J. D. "Automation and education: III. Technology and the instructional process." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 382-94.

11. Gilbert, T. R. "An early approximation to principles of programming continuous discourse, self-instructional materials." Psychological problems and research methods in mathematics training. (Edited by R. L. Feierabend and P. H. DuBois.) Cooperative Research Project No. 642, June 1959.

12. Holland, J. G. "Teaching machines: An application of principles from the laboratory." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 215-87.

13. Klaus, D., & Lumsdaine, A. A. Self-instructional supplements for a televised physics course. Pittsburgh: American Institute for Research, 1959. P. 27.

14. Lumsdaine, A. A. The development of teaching machines and programmed self-instruction. New teaching aids for the American classroom. Stanford University, Calif.: The Institute for Communication Research, 1960. Pp. 136-73.

15. Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960.

16. Lumsdaine, A. A., & Glaser, R. "Concluding remarks." Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 563-579.

17. Meyer, S. R. "Report on the initial test of a junior high-school vocabulary program." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 349-66.

18. Pask, G. "Adaptive teaching with adaptive machines." In Lumsdaine, A. A., & Glaser, R. Teaching machines and programmed learning. Washington: National Education Association, 1960. Pp. 349-66.

19. Porter, D. "Some effects of year-long teaching machine instruction." In Automatic teaching: The state of the art. (Edited by E. H. Galanter.) New York: John Wiley & Sons, 1959. Pp. 85-90.

20. Skinner, B. F. Teaching machines. Science. 128: 969-77, p. 972; 1958.

21. Skinner, B. F. "Programming verbal knowledge for automated instruction in schools and colleges." Paper read at Symposium on the Automation of Teaching, American Psychological Association Convention, Washington, D. C., August 1958.

22. Skinner, B. F. "The use of teaching machines in college instruction." Final report to the Fund for the Advancement of Education. August 15, 1958. Pp. 38-40.

23. Skinner, B. F. "The programming of verbal knowledge." *Automatic teaching: The state of the art.* (Edited by E. H. Galanter.) New York: John Wiley & Sons, 1959. Pp. 67-68.