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Teaching Machines and the Learning Process

Only research can probe the strengths and limitations of machine instruction.

SOME school people are ignoring the existence of teaching machines. Some are probably waiting impatiently for communication experts, psychologists, philanthropists and others to design and install perfectly operating machine instruction in their schools. However, most educational leaders are demanding thorough study first and much subsequent research in school settings to ascertain the best uses of teaching machines. The leaders themselves must initiate the needed research and evaluation in their schools in order to make wise decisions.

The teaching machine under consideration in this article presents a programmed series of questions or other information to the student, provides a means for and requires the student to respond to each item in the program, and indicates the correct response to each item after the student has responded.[1] This article is further limited to mechanical and electromechanical machines, devised primarily for facilitating verbal or symbolic learning, rather than psychomotor or affective.

Eliminated from the present discussion are TV and radio, electronic equipment including tape recorders, sound movie films and similar material, typewriters and similar equipment, computers of all types, simulators used in flight and driver education, and all forms of books. Though not discussed further, TV in many subject matter areas and electronic equipment in foreign language, speech, and shorthand show considerable promise for improving instruction. Combinations of these, of course, may be successfully incorporated into complex machines.

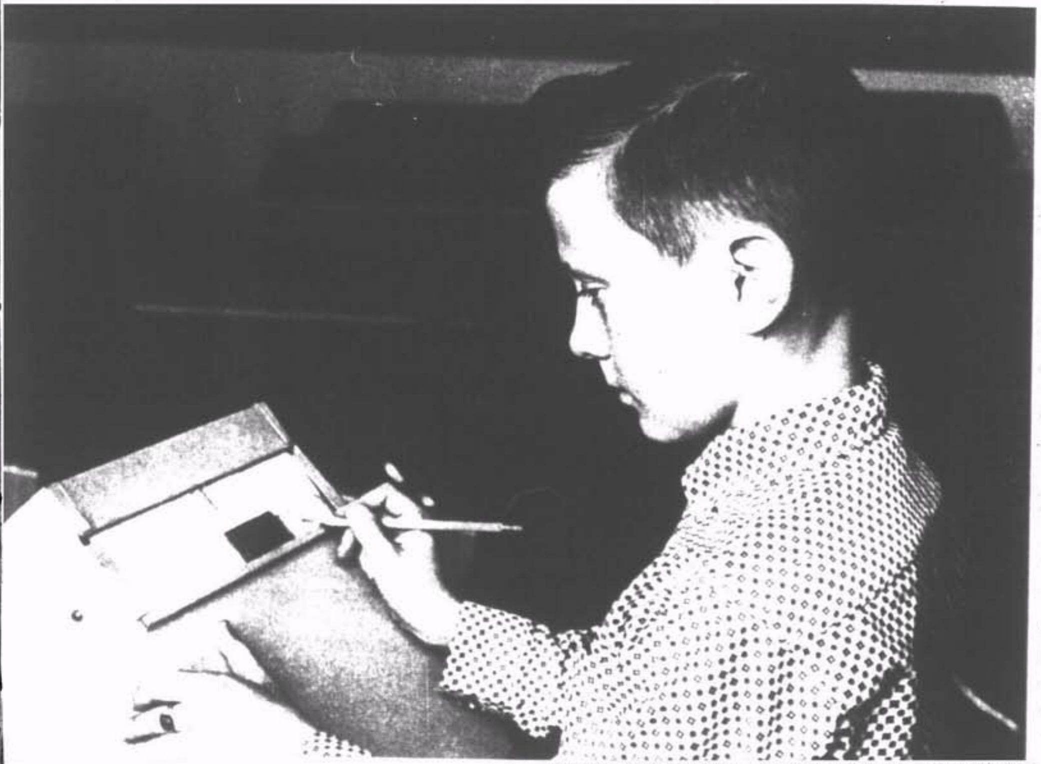
Theoretical Basis of the Teaching Machine

The teaching machine is based upon three widely discussed conditions of learning — operant conditioning, contiguity and repetition.[2]

Pavlov demonstrated that hungry or thirsty animals, under control of the experimenter, could be conditioned to make

[1] J. D. Finn. "Teaching Machines." *NEA Journal* 49:41-44; November 1960. (This article gives verbal and pictorial descriptions of five machines.)

[2] E. R. Hilgard. *Theories of Learning*. New York: Appleton-Century-Crofts, Inc., 2nd. ed., 1956. (Hilgard interprets various theories; the present authors make the applications to teaching machines.)



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The teaching machine presents a series of questions or other information to the student.

a response to a new stimulus that previously had not elicited the response. Skinner bypassed this traditional approach to conditioning and proposed operant or response conditioning. He demonstrated that hungry or thirsty animals, under the control of the experimenter, could be conditioned to make a specific response or a series of responses rapidly when rewarded by the experimenter directly or by a mechanical arrangement. His ideas concerning conditioning have resulted in dramatic improvement in training animals, and have led directly to the recent high interest in machine instruction in the schools.

The teaching machine being discussed is thus firmly based upon principles of conditioning that imply controlling the student and what he learns and rewarding the student, reinforcing, or confirming the correct response as soon as it is made. The proper incidence and spacing of reinforcements in a complete program and the proper amount of repetition can be ascertained and controlled through study and use of the program.

At this point four significant questions for educational practice emerge: (a) Which outcomes of learning are adaptable to machine instruction? (b) Which outcomes of learning can be programmed successfully? (c) Can a student acquire the outcomes more efficiently when using a machine than when participating as a

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member of a larger classroom group in listening to the teacher, discussing with the teacher and classmates, studying independently, reading books, and the like? (d) To what extent will the responses learned by use of the machine transfer to non-machine situations?

Outcomes Adaptable to Machine Instruction

Factual information is more readily adaptable to machine instruction than are other outcomes of learning such as attitudes and values, concepts, skills, problem-solving techniques, creative expression and personality integration.[3] Facts, of course, are important in all the latter outcomes, including concept attainment. Consider now the nature of factual information and concepts in relation to teaching machines.

A fact is something that has happened, an event, an actual state of affairs which is widely accepted as correct or true. The correct pronunciation and spelling of each word; the names given to the symbols in mathematics, music, and science; the foreign language equivalent of each English word; the location and names of geographical places; the time, place, and occurrence of historical events—all of these exemplify factual information. Much of the factual information possessed by mankind can be put in question or other form and the responses the learner makes can be judged as correct or incorrect. Further, the correct response can be supplied in a machine program, thus serving as a reinforcement or reinforcing stimulus if the response is correct and serving as an immediate correction if the response is wrong.

[3] H. J. Klausmeier. *Learning and Human Abilities: Educational Psychology.* New York: Harper & Brothers, 1961. (Principles applying to efficient learning of each outcome are presented.)

A concept depends partly upon factual information but is more than an addition or integration of many facts in symbol form. For example, what man knows about birds can be put in words and other symbols. Yet, though a nine-year-old child has all of the information he can verbalize about birds, his concept of bird will be far poorer than if he has the information but also has seen, heard, and touched a number of different birds. The teaching machine cannot provide the realistic experiences which are necessary for the full attainment of many concepts.

Programming the Material

Developing excellent programs to elicit the student's response is more complex than writing a series of textbooks, courses of study, or curriculum guides. The programmer must decide all the responses to be made by the machine user, the best sequence of material to elicit the desired responses, and the proper amount of repetition and related reinforcements to assure permanent learning. Assuming that the machine instruction is to be self-contained, with the teacher providing no new or supplementary information, the programmer must start with readiness material and gradually, bit by bit, lead up to each final desired response or sequence of responses.

Programs are being developed first in instructional areas such as spelling, in which the factual information is self-contained, and in symbols, most systematically organized, and least subject to more than one interpretation. The correct spellings of all words are already incorporated in dictionaries and considerable research is already completed on difficulty and frequency of use of English words. If one accepts the idea that learning to read is simply learning to pronounce the words correctly, reading instruction can also be programmed but with more difficulty than spelling since a verbal rather than a written response is required. There is no reason to believe, however, that an audio device cannot be incorporated in a more complex machine to give correct pronunciations and thereby permit reinforcement of correct verbal responses, as is the case with the electronic equipment widely used in foreign language instruction.

Now follows a sample of Porter's [4] program in spelling:

1. Underline these words: *thunder, steady, soaked, frightened*

I hadn't gone half way when thunder rolled and rain came down in a steady pour. I was soaked. I made a dash for an old horse shed. And there was Wolf. Crouching in the shadow, he looked so like a wolf that for a moment he frightened me.

frightened steady thunder soaked

2. Circle the word that rhymes with *ready*?

thunder steady pour soaked

steady

3. Circle the word that means firm, regular, or not shaking:

steady thunder umbrella southern sweeping

steady

4. Write the missing letters:

Then rain came down in a s_ea_y pour.

steady

5. Write the missing letters; they are all the same:

Ragged clouds were sw__ping the south_rn sky. *sweeping* *southern*

[4] D. Porter. "Some Effects of Year Long Teaching Machine Instruction." In E. Galanter, Editor, *Automatic Teaching: The State of the Art*, New York: John Wiley & Sons, Inc., 1959. p. 86, 87.

6. Write the missing letters:

Without thinking of an umbre__a, I set out.

umbrella,

7. Write the missing letters:

Halfway to the store thu__er rolled.

thunder

8. Write the missing letters:

Then rain came down in a s_ea_y pour.

steady

9. Write the missing letters:

Brushing, moving quickly, s_ee_ing.

sweeping.

Notice that a relatively high level of reading is required for use of this part of a program in learning to spell. The italicized word or words under each item are presented in a box immediately after the student responds and serves to inform him of the correctness of response or to provide the correct form if he has not responded correctly.

Efficiency of Machine Instruction

Few educators deny that learning factual information as defined previously is and should be required in many instructional fields, primary through graduate school, and that much of the factual information must be memorized originally and then reviewed. Yet the amount of repetition and subsequent memorizing of the same factual material at successive school levels is a serious indictment against the instructional procedures currently employed. The principal problem here is that many teachers are presenting the same material to all individuals within the class but the students are neither acquiring nor remembering it efficiently. The original learning is inefficient in part because students cannot learn at the same rate and in part because one teacher working with a classroom group of 25-35 cannot provide either the proper amount of reinforcement or confirmation at the right time for each student nor can he help each student to identify and overcome errors immediately.

Permanent learning of factual material is facilitated when the learner wants to acquire, retain, and use the facts; the facts are organized into appropriate learning units; the learner makes the correct response on the first try; correct responses are reinforced and errors are corrected immediately; distributed practice is carried out until the facts are firmly established; and each individual proceeds at a rate appropriate for him. It is entirely possible that these conditions can be incorporated into machine instruction for individuals within a class better than any teacher can incorporate them into daily activities with a group of students in a classroom.

However, for machine learning of factual material to be efficient, an approach to curriculum and instruction different from that in many schools must be accepted; namely, each student must be encouraged to proceed at a rate suitable for him. In some schools today, the highly proficient fourth-grade children are not being permitted to study the fifth- and sixth-grade spelling lists; and the less proficient are held to the fourth-grade list even though the second-grade list is better suited to them. The same is true in many other instructional fields, particularly in high school and college, where teachers expect students to somehow acquire identical amounts of factual material in the same amount of time.

Final answers as to which outcomes, besides facts, might be acquired more efficiently by children and youth of varying characteristics through machine than non-machine instruction wait upon further research. The authors believe that machine instruction as currently conceived promises greatest effectiveness for the type of factual information previously illustrated.

Transfer

What are the possibilities for transfer of machine-acquired responses to other situations? Four generalizations about transfer of learning must be considered. First, general information, principles, methods of study, attitudes and values, and methods of adjustment transfer more readily from one situation to another than do technical information, isolated facts, and specific skills or responses. Second, outcomes acquired with meaning transfer more readily than do those acquired without meaning by rote memory and repetition. Third, outcomes which are learned well originally, and therefore are not forgotten, transfer more readily than do those not learned well. Fourth, the learner must perceive how present learnings apply to other situations.

The main possibility for better transfer from machine instruction is in connection with the third generalization. Machine instruction may lead to more thorough learning originally. Also, some programmed material may be more meaningful than the same material which is currently presented in textbooks, work books, and orally by the teacher. We may expect verbal learnings acquired by machine use to transfer to other situations in a fashion similar to that between learning to spell correctly in school and then spelling correctly the same words outside the teaching-learning situation.

Research on rigidity and set in problem solving shows conclusively that when an individual experiences repeated success in solving problems with a certain method or instrument, he clings to that method or instrument even though it is inappropriate for solving new problems he encounters for which other methods and/or instruments are appropriate. Thus, through widespread and repeated use of machines and the method of learning incorporated therein, students may become highly dependent upon someone else to decide for them what to learn, how, why, when, and how well to learn it. This could lead to negative transfer to non-machine learning situations and to lack of sensitivity to problems, of originality, and of flexibility. Also on the negative side with respect to transfer from machine learning is the possibility that many outcomes cannot be acquired with meaning; further only verbal applications of new learning can be presented in the teaching machine.

Here enters a critical value judgment about education. What is education? Drawing out by the teacher and seeking by the student, or putting into the student correct responses and satiating him? Machine instruction, as indicated in the previous discussion of theoretical bases, is designed to encourage the learner to respond correctly or appropriately, as determined by the programmer. The better and more widespread the machine instruction, the more fully must the learner come to rely upon it as the most efficient way for him to learn.

Research, Not Rejection or Faith

The above extreme viewpoints about education are not as black and white as described. However, the possibility of negative transfer should not be ignored. At present, little or no research has been reported about the extent to which machine instruction of any outcomes may produce positive, negative, or no transfer to non-machine situations.

The previous discussion presents some of the strengths and limitations of machine instruction. The two authors do not agree completely on the emphasis given to various points, but they agree fully that educational leaders responsible for learning in school situations must somehow mobilize efforts and monies to conduct essential research and evaluation concerning machine instruction. The schools cannot afford to introduce new practices and equipment on good will, faith, and salesmanship in the absence of research; nor should they prevent more efficient pupil learning because of traditions, institutionalized impediments, or apathy.

Educators employed by the schools, with assistance in research design and evaluation procedures from others as necessary, should seek answers to the questions previously raised and these:

1. Which human abilities can be nurtured effectively through machine use? For example, can the ability to communicate orally in a foreign language, the ability to spell correctly, the ability to work well with others, the ability to identify and solve problems, be nurtured equally well with machines?

2. Is machine instruction equally efficient with all age groups? For example, will first graders learn as well as high school seniors?

3. How long will students of any age respond with high motivation to machines? For example, if half the instruction is incorporated in machines, will students use the machine without teacher forcing for a week? month? year? six years? twelve years? Will they want to learn from machines throughout life, as many now do from books and other printed material?

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programs were initiated, the nature of instruction, reporting pupil progress, guidance practices, types of core, preparation of core teachers, and chief obstacles to development of core programs. Responses were secured from both principals and teachers.

The Illinois report reflects a sense of the importance of core-type classes for the junior high school. Indeed, it suggests that this type of class is likely to increase still further to provide the common learnings needed by junior high youngsters. At the same time, it underscores the need for urgent attention to the preparation of junior high school administrators and teachers in general and core-type teachers in particular.

New York State Education Department. *Exploring Space,* a Resource Unit for a Course in Physical Science. Albany: Bureau of Secondary Curriculum Development, 1957. 94 p. (Price not indicated.)

Very few topics in the education of youngsters today have the power to stimulate the imagination to the extent that the topic of this resource unit does. At the same time it offers many opportunities to study basic laws of science in several fields and to see the interrelationships among them. As might be expected, special emphasis falls to astronomy and radio astronomy.

Three sections of the unit include: (a) The Earth's Atmosphere, (b) Exploring Space from the Earth, and (c) Exploring Outer Space. Numerous activities are suggested to explore the principal scientific concepts involved in space study. Individual aspects of the total unit lend themselves well to separate study, e.g., "Exploring Space from the Earth." General goals are clearly stated in the beginning, and a Preteaching Checklist should be of special value to teachers using this material.

The unit closes with detailed lists of equipment and supplies, useful films, and readings. The references were carefully chosen for their scientific accuracy and value, in order to help youngsters recognize the limitations of certain science fiction writings which often permit imagination to disregard established fact or inescapable laws of nature. The entire work is profusely illustrated. It should prove to be of practical value to teachers of science in our emerging space age.

Machines and Learning Process

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4. Can a program of instruction be arranged in the school system which encourages each student to proceed at a rate appropriate for him, kindergarten through twelfth grade? Though this idea is accepted by many at the verbal level, the authors are unaware of any school system that actually accomplishes it well. And there is no point in introducing machine instruction unless it is accepted in practice. Children can be denied the opportunity for using appropriate levels of programmed material, as, for example, many of the more proficient sixth graders are now being denied use of any of the required textbooks or other instructional material used in the seventh grade.

Little doubt exists that relatively inexpensive machines and programs in such fields as spelling and arithmetic throughout the elementary school level will soon be available. If the producers and manufacturers cannot sell them to the schools directly, they will sell them to parents, just as encyclopedias, dictionaries, and non-textbook materials are now sold.