Vol I No. 1 Feb., 1962 Teaching Machines and Language Laboratories

THE AUTOMIZATION OF SOCRATES

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This introduction to teaching machines presents the major features of automated instruction and some of the problems involved in the area. Mr. Cook, formerly in the Departments of Education and Psychology at Purdue University, is now associate professor in the Bureau of Educational Research and Service at The Ohio State University.

THE Socratic Method, long used in classroom instruction, consists of a series of probing questions and statements presented by a teacher to a student to develop knowledge, understanding, and insight on the part of the student with regard to some specified goal. The progression of questions or statements is determined by the prior learning gained by the student at each step along the road to the particular goal set by the teacher. Many teachers have employed this method or one similar to it in informal discussions with students, but its extensive use is restricted when classroom size is large. It is certainly inappropriate in a classroom recitation period where a single teacher asks questions of a large number of students, since it requires a one-to-one teacher-pupil relationship.

The question might now be asked, How does *automization* fit into the picture? This is best answered by saying that procedures are currently being developed to replace the *live* teacher in certain activities, Socrates in the present context, with a device which would provide the student with individualized instruction or tutoring under conditions possessing the desirable characteristics of the Socratic Method. In brief, this is a mechanical instructional system which permits the direct interaction of a student with an individual tutor through a planned program of questions, exercises, and problems. It might be an *automatic tutor,* a *self-instructional device,* or a *teaching machine.* In such a system, the responses of the student would be observed and evaluated, and the program adjusted to the rate of the student's learning. The device would make better use of the teacher's knowledge of both human learning and subject-matter to bring about more efficient learning.

The program developed is specifically designed to move the student through a desired sequence by a series of small or atomistic steps. The device is so constructed that the learner receives information, or *feedback,* as to the correctness or appropriateness of his responses at each step along the way. Depending upon the nature of the device and the performance of the student, new material can be presented or the previous material repeated until the learner has achieved a level of understanding designated by the person who developed the instructional program. To the extent that such a device possesses mechanical features designed to facilitate the presentation of the program to the student and to record his responses, it may be called a machine. As we shall see later, however, this same system can be achieved without the use of any mechanical device.

As Carr (1959) and Stolurow (1961) point out, what we are actually talking about is a communications system containing three basic elements: the machine, the student, and the program. It should be noted that the mechanical device or its substitute cannot be considered apart from the other two elements. Although the term *teaching machine* has caught the public's fancy, it can be properly applied to such systems only if consideration is also given to both the instructional program and the interaction of the student with the other two elements.

THE origin of the teaching machine has generally been ascribed to Skinner of Harvard University (1958). Some of the basic principles involved, however, were employed by Pressey (1926) when he developed a mechanical testing device that provided students with immediate information regarding the correctness of their responses. Pressey recognized that under certain conditions this could also be used for teaching. Mager (1959) points out that in 1866 a patent was issued for a device employing many of these same basic principles. The popularization of the teaching machine, however, has come about within the last few years, with the development of the first practical model by Skinner in the late fifties. This model was derived from his work with pigeons and other animals in developing certain desired behaviors under controlling conditions. The field has expanded rapidly since then and now includes techniques which are not purely mechanical. From the simple machine developed by Skinner, there are now more than forty devices on the market. The available literature on the subject numbers well over one hundred articles, as contrasted with a relatively few published articles in the early fifties. With this explosion of both development and research about teaching machines, and the self-instructional field in general, the term *teaching machines* is no longer truly appropriate. Many broader terms have been suggested to replace it so as to take into account the basic nature of the devices and the wide variety available. Among these are *auto-instructional devices, programed instruction, programed learning,* and *self-instructional devices.*

A common question asked revolves about the role of teaching machines in the total instructional situation. Are they designed to replace the normal instructional pattern, or are they just another aid? One can find adherents for both positions. To understand their possible role better, it might be advisable to take a look at both the general place of such devices in the instructional-aids spectrum and some of the principles of learning underlying them.

Porter (1957) recently summarized the literature on the various types of available teaching aids and devices. He divided them into *Stimulus, Response,* and *Stimulus-Response* groups. *Stimulus* devices are primarily teaching aids that present material through one of the senses without requiring any active participation from the students. Examples of such devices are television, sound motion pictures, radio, and tapes. *Response* devices are aids which allow students opportunity to practice desired responses, but do not in and of themselves present any stimulus material. Some examples are the desk calculator and the typewriter. The *Stimulus-Response* group consists of devices that not only present material but also require an active response from the student. This category includes teaching machines and other self-instructional aids and, therefore, in this context requires a more detailed examination.

The *Stimulus-Response* group includes *Simulators, Pacers,* and *Immediate Reinforcers. Simulators* are devices which attempt to duplicate real situations as nearly as possible—for example, grounded space capsules and the Aetna Driving Machine. *Pacers* are probably more familiar to school personnel. Examples of these are the reading accelerator, reading films, and the tachistoscope. Teaching machines and other programed instructional devices are classified as *Immediate Reinforcers.* These operate according to fairly well-established principles of learning and therefore possess certain common features.

First, provision is made for continuous *active* student response to a carefully worked out series of exercises. This feature is based upon the principle that the learner learns only what he *does.* Second, there is prompt feedback to the learner regarding the quality of his response to each part of the program. This feature is based upon the principle that prompt knowledge of results can serve as an effective reinforcing agent in directing the learning process. Skinner stresses this strongly in his arguments favoring teaching machines. He maintains that the typical classroom teacher does not have the time during the normal school day to provide adequate reinforcement for all the necessary learnings the student is asked to develop. Hence, according to Skinner, students are never really sure of what they should be learning and whether or not what they are actually learning is correct. Third, many of the devices permit the individual student to set his own pace. This feature takes into account the principle of individual differences in respect to learning and performance rates.

Of the various types of *Immediate Reinforcers,* the teaching machine and its nonmechanical counterpart, the *programed textbook,* are receiving the most attention at the present time. Both of these techniques have three basic characteristics. First, there is some type of *display panel* which presents the programed material—that is, the question to be answered or exercise to be completed—to the student. Second, there is a *response panel* through which a student can either (a) choose one of several possible responses presented or (b) construct, fill in, or write out his answer. Third, there is a *confirming-reinforcing mechanism.* This is the means by which the learner receives feedback as to the correctness of his response. It is usually accomplished by having the student manipulate the device so as to expose the *correct* answer. Most persons concerned with teaching machines agree that this confirming-reinforcing mechanism motivates the student to operate the device further and thus continue his learning. Although knowledge of successful performance is considered to be enough reinforcement, some type of extrinsic reward may be provided.

Let us now take a look at actual mechanical teaching machines that have been developed. Figure 1 illustrates some of these. Note the last two items at the right in the second row. The first one is the Pressey device as developed in 1927. Immediately adjacent to it is a punchboard device developed later by Pressey. These two are not actually teaching machines but they implement a major principle by providing the student with immediate knowledge of correctness of response. Thus, the grandfather of all teaching machines could well be the 1927 Pressey device. The immediate father of most current machines is the Skinner Disk Machine, which appears in the upper lefthand corner. Briefly, a series of questions

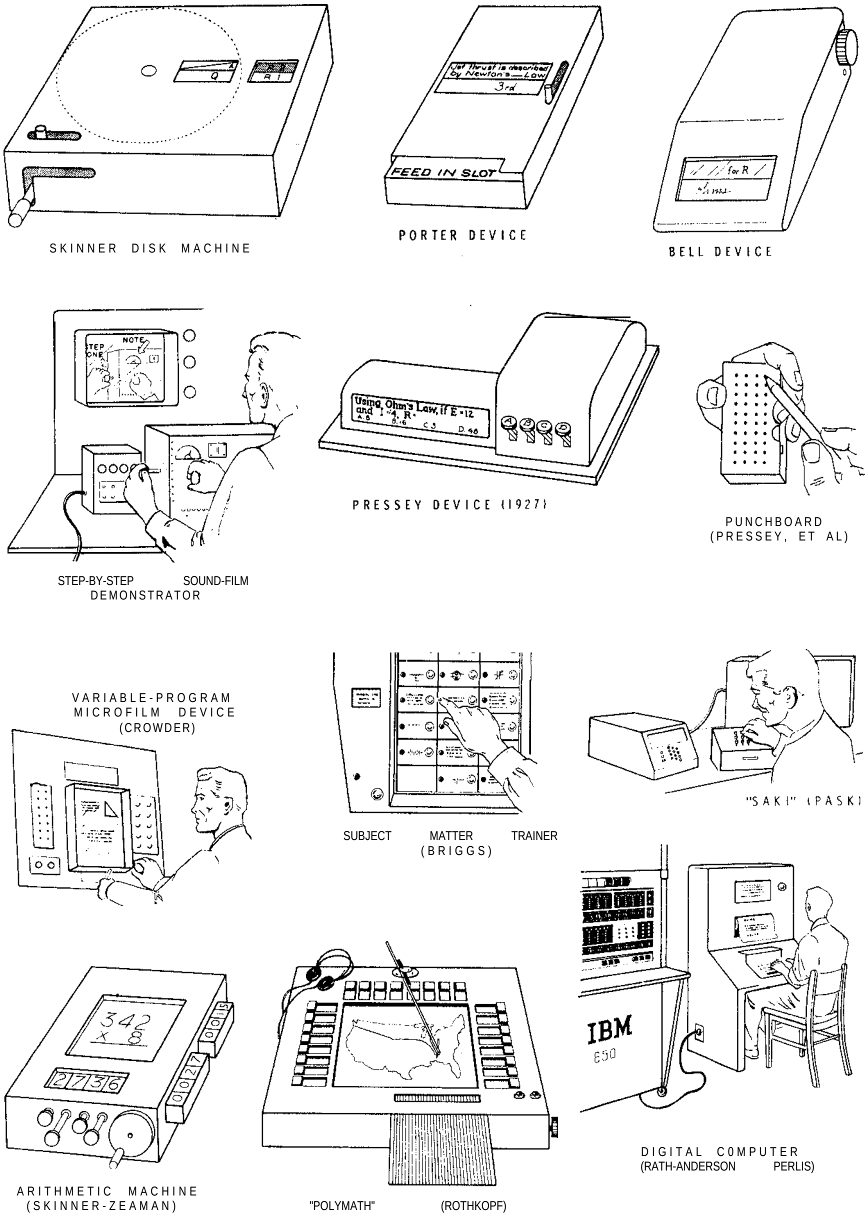

FIGURE 1. REPRESENTATIVE TEACHING MACHINES ILLUSTRATING VARIOUS CHARACTERISTICS. FROM A. A. LUMSDAINE, "THE DEVELOPMENT OF TEACHING MACHINES AND PROGRAMMED SELF-INSTRUCTION," *New Teaching Aids for the American Classroom,* 1960, P. 162, BY PERMISSION OF THE PUBLISHER, THE INSTITUTE FOR COMMUNICATION RESEARCH, STANFORD UNIVERSITY.

or statements along with answers is prepared on a disk (represented by dotted line) and inserted into the machine. One item at a time is visible to the student as it appears in the window marked Q. The adjacent desired response, located at A, is not visible until the student has written his answer on a paper tape at the right, or at RI. When he has made a response, he moves a lever at the lower left. The result simultaneously exposes the correct answer at A and moves the student's answer under the transparent cover to R2, where he can see it but can no longer change it. The student now compares his response with the desired one. If he decides that his is correct, he moves the other lever to mark the tape. By manipulating the lower lever again, he exposes the next item.

The Skinner device is the one that most persons refer to when they are talking about teaching machines. The other models illustrated are variations of the basic idea of controlling, through reward, the sequence of operations performed by an individual. Those in the top row are essentially free- or constructed-response devices and require some judgment on the part of the student as to the correctness of his answer. The devices in the next two rows are choice-type ones, which do not require the student to make a decision as to the correctness of his response. It should be noted that the devices illustrated in the first three rows do not permit the student to look ahead or backward in responding to the program. Each item is exposed as a single unit. On the bottom row are devices employing a combination of the mode of response as well as control of material to be presented. Some of these are relatively simple, such as the arithmetic machine at the left, while others, like the IBM digital computer (lower right) are fairly complex.

THE second of the three essential elements of a programed communications system is the program itself. The organization of the program is crucial, since it directs the student through the learning sequence. At the present time, there are two methods of programing material. Each has strong advocates.

The first method, based on the principles developed by Skinner, is commonly referred to as *linear, fixed-sequence, straight-line,* or *extrinsic* programing. In this type of program, exemplified in Figure 2, small units of materials, called *steps,* are presented to the student. By the use of various types of cues and prompts, a desired response is gradually *shaped* by eliciting it from what the student has already learned. Each step of the program has to be completed; no provision is made for modification of the sequence according to the learner's responses to earlier material. Individual differences are provided for in that each student can work at his own rate of speed. The linear program usually requires the student to *construct* his response by writing or typing an answer or by manipulating dials to make the appropriate response. Skinner believes that this construction process is a fundamental aspect of

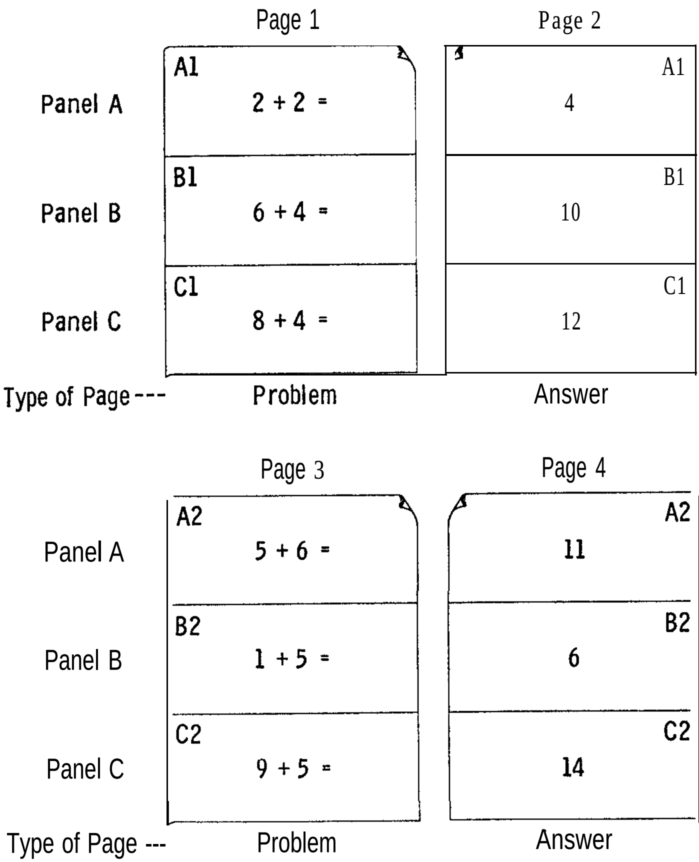

FIGURE 2. SUCCESSIVE PAGES IN A LINEAR PROGRAMED TEXTBOOK. FROM LAWRENCE M. STOLUROW, *Teaching by Machine,* 1961, P. 38, BY PERMISSION OF THE PUBLISHER, COOPERATIVE RESEARCH DIVISION OF THE U. S. OFFICE OF EDUCATION.

learning. The linear method of programing can be seen in the machine and textbook programs currently being produced by TMI-Grolier; in *English 2600* published by Harcourt, Brace, and World, Inc.; and in *TEMAC* by Encyclopedia Britannica.

The second approach to organizing instructional material, referred to as *nonlinear, branching,* or *intrinsic* programing, is illustrated in Figure 3. Material is presented to the student either in small sequential steps or in larger units (sometimes even in paragraph length). In devices using this method, the response commonly, though not always, involves a choice, as contrasted with the construction of the response in the linear method. Depending on the response made, new or remedial sequences can be presented. Such a method is much more flexible than the linear program for meeting individual differences not only in the rate of work but also in the quality of response.

The inclusion of alternate or branching sequences of material often raises the cost of such programs because of the complex mechanical system needed to present them. The essentials of such programing methods, however, can be employed inexpensively, as evidenced by the *TutorTexts* in bridge, algebra, and computer arithmetic. Commonly referred to as *scrambled* books, these are currently published by Doubleday and Company under the direction of Norman Crowder. Crowder has the role in the *branching* method of programing that Skinner has in the *linear.*

The efficacy of these two methods of programing material has yet to be firmly established, but research is being conducted in respect to both types and perhaps more definitive answers will be available soon. Both methods have been employed with mechanical devices and programed textbooks. The cost of developing both the book and machine program is very high, running into the thousands of dollars. After initial development, however, the programed textbooks are much cheaper to produce than are most machine programs. Many current books cost between five and ten dollars.

IN THE above paragraphs, I have tried briefly to describe what is currently meant by a teaching machine. The instructional feasibility of such devices is still unresolved. I would like to take a moment to discuss some of the major problems.

Perhaps the most crucial problem area is that of *programing* material. It involves the determination of the most desirable arrangement of the instructional material so that specified educational objectives can be achieved. In discussing the influence of programed learning on educational practice, many writers assert that if it has no other beneficial effect on educational methods, at least it will require a thorough examination of how subject-matter is organized and how it can best be learned by a student. Programers for teaching machines will have to be not only curriculum specialists but students of the psychology of learning as well. Because of the importance of the program, school personnel should

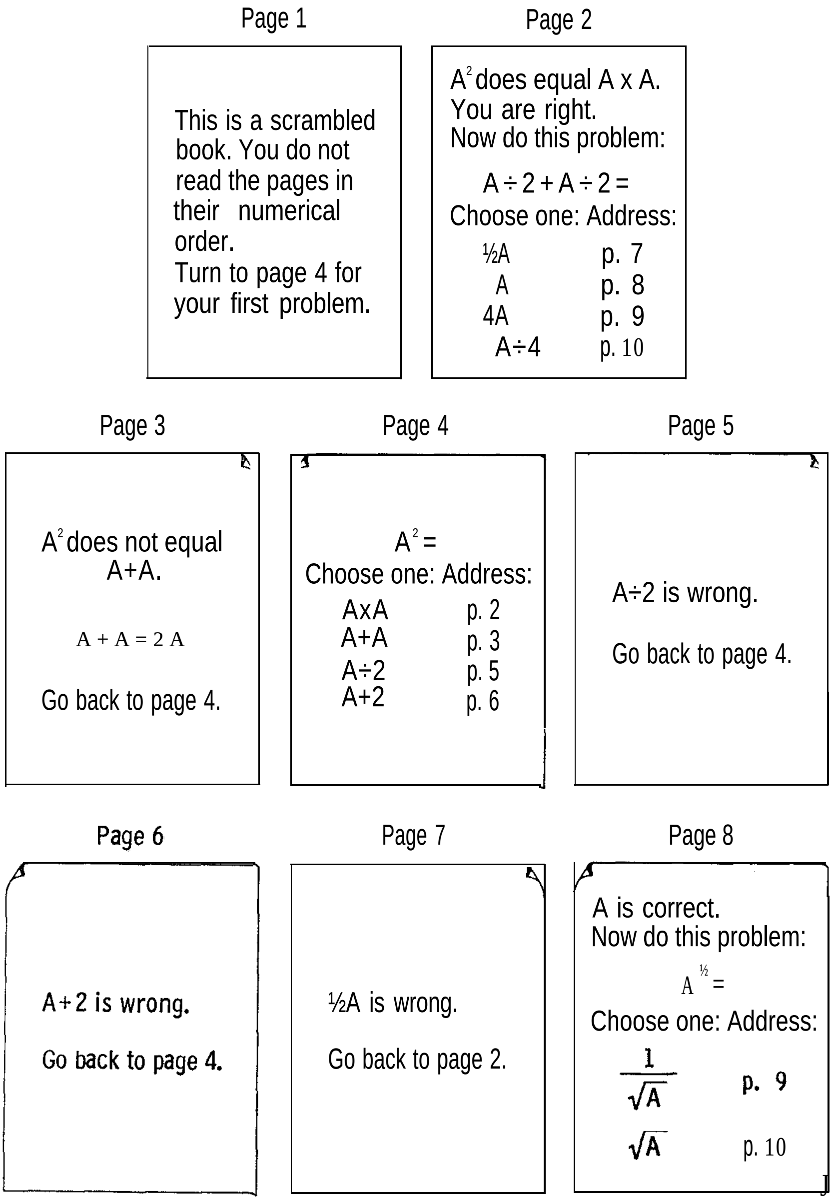

FIGURE 3. SUCCESSIVE PAGES IN A CROWDER SCRAMBLED TEXTBOOK. FROM LAWRENCE M. STOLUROW, *Teaching by Machine*, 1961, P. 39, BY PERMISSION OF THE PUBLISHER, COOPERATIVE RESEARCH DIVISION OF THE U. S. OFFICE OF EDUCATION.

be more concerned with this aspect of teaching machines than with the mechanical devices themselves.

A second major problem is that of *step size,* or how much material should be included in the individual steps of the program in order to achieve efficient learning. We need to know if the brighter student can utilize smaller steps or larger segments of material presented at any one time than the less able student.

Still another problem involves the number and types of *prompts* or *cues* that should be provided, particularly in learning from the linear method of programing. Generally, it has been demonstrated that the student can function with fewer and fewer cues as he establishes greater efficiency in the desired learning. We still do not know exactly what types or number of cues are most effective.

Determination of the best *response mode* — construction or choice — is another unresolved problem. Skinner believes that more effective learning results if the student constructs an answer, while Crowder says that choosing from several alternatives is equally effective. This sounds like the old essay–objective test issue.

Pacing, or the rate at which the individual can work through the material, is still another problem. Linear methods of programing set some limit upon the pace at which the student can work, whereas the branching method offers greater flexibility.

Cost is a problem area of particular concern to school administrators. Current production models of some teaching machines are being sold at around twenty dollars, while others can run into the thousands of dollars. This does not include the programed material, which is often consumable, or the physical facilities for using the machines.

Another major problem, and a serious one, concerns the retention and subsequent use of behaviors learned by programed instruction. This, of course, is the old problem of *transfer.*

IN SUMMARY, this paper has attempted to show how we are trying to update the teaching method of our good friend Socrates to the twentieth century. Education in the years ahead may require new and different procedures than those of the past. Perhaps the automization of Socrates can help solve many of the problems concerned with providing the most efficient learning situation for each individual. However, there are a number of questions which do not yet have answers. As with other new instructional media, a wide variety of research studies is needed and patience is required until answers from such studies are available. We need adventurous individuals in all areas and levels of education to conduct well-designed research studies utilizing these new devices and materials.

What the future holds for teaching machines and other self-instructional devices in the schools and colleges of the United States is hard to say. As techniques for achieving certain educational goals, I believe that they have much to offer. They are psychologically sound, can be highly flexible and adaptive, and are relatively inexpensive when produced in sufficient quantity.

Teaching machines are a challenge to education, for they reflect the trend in our society toward greater automation in our daily living. How we react to this challenge will determine to a great extent the future of education.

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