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Teaching Machines and Auto-Instructional Programs[1]

A rationale of the media and an analysis of the programs.

WE have been hearing a good deal of talk lately about teaching machines. The topic of this paper is somewhat broader than just machines. I want to do two main things. First, I want to indicate something of the rationale and concept of auto-instructional media—of which teaching machines, as such, represent just one aspect. Second, I want to sketch in the complementary aspect of auto-instructional media, by illustrating briefly some characteristics of the self-instructional programs which teaching machines and similar devices can be used to present to students.

[1] This paper is an edited version of a presentation to the Advisory Committee for Title VII of the National Defense Education Act at the Educational Media Branch, U. S. Office of Education, in May 1960, later presented as a briefing for the Commissioner of Education and USOE Staff. For further information on teaching machines and auto-instructional techniques, see the source book, *Teaching Machines and Programmed Learning*, edited by A. A. Lumsdaine and R. Glaser. The references cited in this paper are reproduced or abstracted in this book, recently published by the Division of Audio-Visual Instruction, National Education Association.

To discuss machines without reference to machine-presented instructional materials would be as one-sided and uninformative as if one were to talk about the mechanics of movie projectors without reference to the kinds of educational films they can present to students—or to discuss the structure of a television transmission system without reference to the content of the programs that make the television system a medium of education rather than only one of entertainment.

The concept of self instruction, as incorporated in the teaching machine, is, first of all, a concept of *individual* instruction. This concept is certainly not a new one. One thinks of early man teaching his son to shoot a bow and arrow, of the Socratic dialogues, of Mark Hopkins on the other end of the log. Perhaps such individual instruction is not used more frequently in our academic institutions for only one main reason—because it costs too much. We can hardly afford a student-teacher ratio of 30-to-one; a ratio approximating one-to-one seems economically unthinkable under existing conditions. However, as John Blyth has pointed out, we often do a much better job in approximating the desirable fea-

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tures of individualized instruction for nonacademic teaching—football playing and instrumental music, for example—than we do in academic courses.

Factors Involved

Let us look briefly at some fundamental considerations behind what is beginning to be called the teaching-machine movement. These considerations are basic ones, and they also underlie our more general concern with improved educational media.

Good teachers are scarce, and, at least in relation to demand, are getting scarcer. An exponentially expanding population is constantly making the situation worse. Even considering only the educational needs of the United States, it is debatable whether any remedy thus far proposed can continue to meet the quantitative demand while even holding the line in qualitative standards of the educational output. We need not even consider the even more difficult problems to be dealt with in meeting the educational needs of underdeveloped countries to conclude that there is good reason to look for fundamental improvements in education.

Merely holding the line is not going to be enough, and facing up to what is required in our own educational systems here in the United States brings us to a second set of considerations—those stemming from the technological advances in our society. These considerations are grounded in the fact that man's life from the second half of the twentieth century on is certain to be increasingly and inextricably bound up with the transformation of our world by very rapid and unprecedented technological advances. The extension and inevitable partial replacement of human functions by the digital computer and similar electronic devices have already begun, in a space of hardly ten years, to revolutionize such diverse aspects of our lives as industrial production and research techniques. This is only a bare beginning. Within a matter of decades it seems likely that what Ramo calls the extension of man's intellect through electronics will bring about profound changes in both the requirements and the capabilities of our educational system.

What have these momentous challenges to do with teaching machines? Two major implications seem obvious. The first is the promise, as yet largely unfulfilled, that these very technological advances can and probably must ultimately be used to increase greatly the resources and capabilities of the teacher. The second and more important implication is that accelerated requirements for a technically capable citizenry will impose educational requirements that will strain the inadequacy of our current educational facilities even more sorely than will the needs of our exploding population. In the face of such requirements we must look for approaches to improved efficiency in education that go far beyond what we seem likely to achieve through merely automating the lecture-demonstration by means of films and television.

Educational television is only *one* important approach for coping with teacher shortages and upgrading the quality of instruction. Despite its great potential, it has the disadvantage that often it tends only to automate the mass instructional characteristics of the lecture. The fixed pace of group instruction by film, TV or lecture does not tailor the learning situation to take account of the enormous differences in rate at which students can learn.

I am not suggesting that we sell educational TV short. Research and experimentation on ways to improve its effectiveness are certainly very much in order. But it does seem clear that *any* medium for group instruction—including educational TV, airborne or otherwise—does not offer a full answer to our problems of educational economics. Teaching machines and other forms of individual self instruction represent another, complementary approach which in a real sense has the very strengths that educational television necessarily lacks.

Early Teaching Machine

Individual self instruction, using teaching machines or nonmechanical devices for presenting instructional materials, represents an attempt to apply concepts of learning theory, communication feedback and, to some extent, automation, in order to make individual instruction in academic subject matters a practical reality instead of an educational luxury available only in rare instances. As will be seen, the implementation of the fundamental concepts underlying this attempt depends even more on the programming of instructional material than it does on the nature of mechanical presentation devices. However, several of the basic concepts can be conveniently illustrated by looking at some teaching machines and noting their characteristics.

The forerunner of present-day teaching machines was envisaged in the early nineteen-twenties by S. L. Pressey of Ohio State University. Pressey argued that if labor-saving devices are possible in the home and in the office, why not also in the classroom? Pressey looked at the classrooms of that day—which were not too different from the ones of today—and was impressed with the time consumed by the teacher in scoring endless tests and quizzes. Not only did these fail to give prompt knowledge of results to the student; their scoring usurped an undue proportion of teacher time that might clearly be better spent in more creative pursuits. Out of this conception he developed his machine.

Pressey devised this machine around 1924. It is about the size of a small portable typewriter. A multiple-choice question appears in a window in the machine. The student might answer the question on the basis of prior study of his textbook, a lecture, film, or some other source—*including what he had learned from answering preceding questions in the series*. If he indicates the proper answer, by pressing one of four keys corresponding to the answer-choices provided for the question, the machine tells him he is correct by presenting the next question. But if he is wrong, the question stays in the window, an error is tallied, and he tries again. Pressey's original device also had an attachment for rewarding the student with a piece of candy after he achieved a predetermined number of correct answers.

There are three basic characteristics which this and all other teaching machines exemplify. First, the student learns *individually* at whatever rate best suits his individual capabilities, rather than at a lock-step pace as in usual classroom or lecture presentations. Second, he is required to keep responding actively and appropriately. And third, he receives immediate confirmation or correction for each response that he makes. This means that he does not persist in errors, and is not left wondering where he stands. In

COURTESY DOUGLAS PORTER, HARVARD UNIVERSITY

Figure 1—Children working on a teaching machine program in spelling.

addition, because his response to the materials presented by the machine is a private matter, he is not exposed to ridicule or other aversive consequences as a result of any errors he may make. These are simple virtues, but very important ones.

Despite these potential advantages, teaching machines were not widely adopted during the two decades following Pressey's initial development. This may be possibly because the times were not ripe for their acceptance. Much of the surge of interest that has become so widespread today derives from the impetus given by the work of B. F. Skinner of Harvard.

Skinner recognized that the learning materials presented by a machine can, and probably must, be analyzed very carefully into small specific steps that can be sequenced in an appropriate order so that each step the student takes builds on to the repertoire of behavior and understanding which he has already mastered. Skinner has also stressed the notion that often it is important for the student to construct or compose instead of choosing it. One of the kinds of devices developed at Harvard to implement his concepts is shown in Figure 1.

Each of the children in this group is working individually on a self-tutoring program in spelling. The teaching materials are fed past a double window in the machine. The student writes his responses directly on the teaching materials through the open window. Then he pushes a lever that moves his answer under a transparent piece of plastic. Now he can still see it but can no longer change it. Simultaneously, the correct answer is exposed. Extensive work on spelling using this device has been done by Douglas Porter with second and sixth grade children in the Boston area. The programs of auto-instructional materials develop comprehension of new words at the same time their spelling is learned and practiced. In a report on a full year test of the effectiveness of these machine-presented self-tutoring programs, Porter (1959) has shown that spelling can be taught more effectively than by conventional methods, and also can be taught in considerably less time.

Self-Tutoring Materials

The general way this auto-instructional approach works can be illustrated by some materials in high school physics developed by D. J. Klaus, in collaboration with the writer, under a U. S. Office of Education project on new educational media at the American Institute for Research in Pittsburgh. This project was conducted to assess the contribution of self-tutoring materials used in conjunction with televised physics lessons of the Harvey White series.

The self-instructional materials used in this study consist of carefully organized sequences, or "programs" of questions and answers. Each question-and-answer segment is called a *"frame."* Figure 2 shows a few illustrative frames. The illustrative sequence in Figure 2 is arranged to simulate, in part, the manner in which the individual student is exposed to the question-and-answer panels of successive frames in an auto-instructional program.

The reader may follow this sequence, answering each question, starting at the top of Figure 2, and either writing in the answer for each question in the box or merely supplying each answer mentally before checking his answer and proceeding to the next frame. To follow the progression of illustrative question-and-answer frames for this figure, it is suggested that, in beginning, the reader *cover all but the topmost panel* (A-1) with a card or sheet of paper, thus successively disclosing each panel only *after* filling in the preceding answer box.

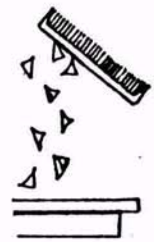
Note that the first few frames in the unit are extremely easy; but before long the student progresses to material of considerable complexity (which he continues to deal with easily and effectively). The asterisk (*) in some of the response boxes is a convention that was used to inform the student that the required answer consists of more than one word. A double asterisk (**) is used in later frames to show that the student should supply an extended answer, using his own words.

As the student responds to later frames, he develops familiarity through active

FIGURE 2

A-1

A very important discovery in physics was the mutual attraction of objects due to static electricity. If we rub a hard rubber comb with a wool cloth and hold it over bits of tissue paper, the comb will attract the paper. This attraction illustrates [ ] electricity.



a-1

static

A-2

At parties, you have probably seen someone rub balloons against a wool rug to make the balloons stick to the walls or ceiling. This is another example of [ ].

a-2

static electricity

A-3

In [ ] electricity, some objects will attract each other. A hard rubber comb rubbed against wool will [ ] bits of tissue paper.

a-3

static
attract

practice by responding in varied contexts with the concepts "attraction," "repulsion," "charge," "positive," "negative," "like charges," "unlike charges," and so forth. The student, working at his own pace, practices using each term, concept and relationship in a variety of contexts and in applications of increased complexity until he has developed a thorough working command of this portion of the subject matter. This takes about ten minutes for a bright student, and up to thirty minutes for a slow student. All students, however, are able to respond with consistent correctness to a range of questions of increasing difficulty. By the end of a sequence of about thirty frames, the student is able to state in his own words the general rules for attraction and repulsion of electrical charges. Also, he has acquired a rich association of meaning and understanding of the concepts by repeatedly using them in varied contexts.

These auto-instructional materials cover approximately six weeks of instruction in the second semester of physics, and comprise about *3,000* separate question-and-answer "frames." The importance of the auto-instructional *materials* themselves—as being distinguished from a teaching machine that could automatically present them in sequence—is brought out by the fact that, in experimental research thus far, they have been presented in *book* form rather than by machine. In the "programmed" books used in these studies, the correct answer to the question frame given on each page is always presented on the *following* page, so that the student checks his answer to each frame by turning to the next page. He then goes on to the following frame on the next page, and so on through the booklet. These materials can also, however, later be used in a compact, low-cost film machine.

Figure 2 on opposite page—Illustrative frames from a program in high school physics.

(COURTESY D. J. KLAUS AND COLLABORATORS, AMERICAN INSTITUTE FOR RESEARCH.)

Last spring the 3,000 self-tutoring "frames" were used in book form by fifteen high schools in the Pittsburgh area. (These units complemented the daily TV lessons on electricity and light in the Harvey White physics films transmitted five days a week over Pittsburgh's Metropolitan Educational TV Station, WQED.) Test results for experimental classes in which the self-instructional materials were made available to supplement the televised physics course were compared with those of control classes which did *not* receive the self-tutoring materials. The test results demonstrated that the use of the materials made a significant contribution to the student's achievement. This was true even though the use of the materials was voluntary rather than a mandatory requirement.

Similarly encouraging results have also been obtained in trying out teaching-machine programs in school situations by Eigen and Komoski at the Collegiate School in New York City and by Allen Calvin in the Roanoke, Virginia, Public Schools. Numerous further tryouts are being conducted during the current school year in various locations around the country.

Use of teaching machines has also been explored with encouraging results for preschool children. J. G. Holland of Harvard (1960) has described a device for teaching children to discriminate symbol patterns and other shapes, irrespective of other cues such as color or size. The child learns to select one of three patterns to match each of a series of

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first grade teacher "teach" reading to a class of 50 children by encouraging the pupils to teach each other. While they learned at various rates, the teacher was free to help those with special needs or problems or even to talk to visitors.

With the flexible program I envisage, there would be no need for special classes for "exceptional" children. Within the walls of a single room, each pupil would be encouraged to think for himself and to do for himself, to be creative, to observe accurately, to test new ideas and to develop judgment based upon his own experience. He would learn how to have freedom and how to use it constructively to grow and develop optimally, and also how, within this freedom, to listen and to learn from others. He would learn how to live with and extend his own uniqueness; and at the same time live with and grow through the uniqueness of others.

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Teaching Machines

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stimulus patterns. Discrimination is developed by rewarding only the correct response.

What impact can we expect the use of teaching machines and auto-instructional programs to have on education during the next ten years? One answer has been given by the writer and Robert Glaser in the concluding chapter of our recent book, *Teaching Machines and Programmed Learning.*[2] Our conclusions were as follows:

Teaching machines and programmed learning can have a major impact on education. Their use can effectively and dependably guide the student's learning-by-doing as he proceeds, as rapidly as his abilities permit, through carefully pretested instructional programs. It can thus be made economically feasible to provide every student with many of the benefits of a skilled private tutor, since auto-instructional materials can anticipate and be responsive to his needs for mastering each aspect of a subject matter. Not only do programmed materials themselves thus have the potential for producing much more efficient learning than has hitherto been generally possible, but their wise use should make possible the much more constructive use of the teacher's talents.

The basis for consistent improvement in educational methods is a systematic translation of the techniques and findings of the experimental science of human learning into the practical development of an instructional technology. To achieve the full benefits inherent in this concept, instructional materials and practices must be designed with careful attention to the attainment of explicitly stated, behaviorally defined educational goals. Programmed learning sequences must be developed through procedures that include systematic tryout and progressive revision based on analysis of student behavior.

The rate at which the methods of programmed learning may influence the practices, staff and facility requirements of school systems is difficult to predict. However, it seems likely that we can look forward to significant revisions in concepts of classroom practices and teacher functions. We also need to foresee and plan for the time when, because of increased instructional effectiveness, a much more advanced range of educational content can be included in the precollege curriculum.

[2] National Education Association, The Department of Audio-Visual Instruction. *Teaching Machines and Programmed Learning.* A. A. Lumsdaine and Robert Glaser, Editors. Washington D. C.: the Department, 1960. p. 572.