Comes the Teaching Machine

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Possibilities of the new "programmed learning" in application to intelligence training.

COMES THE TEACHING MACHINE

At last the technological revolution, by which luxuries once available only to the wealthy few and new marvels undreamed of even by them become the common birthright of the masses, is about to invade the classroom and despoil the sanctuary of a relationship between instructor and student essentially inviolate since the days of Aristotle. This relationship, reflected in the age-old image of a teacher discoursing to a group of students, represents quite precisely an educational philosophy to which everyone has more or less adhered for generations-that the teacher's responsibility is to teach, and learning is the student's job. The teacher should know his material thoroughly, organize it clearly, and present it effectively. In the United States, by exception, the good teacher is supposed also to answer any reasonable questions put by his students and to be generally helpful and encouraging; but there his job ends. It is up to the student to master the new material, think through its implications, and apply it in practice.

This philosophy holds it important that the student shoulder his responsibility for the effort to learn. To that end teachers have been wont to confront him with challengingly difficult materials in order to stimulate him to "pay attention," "use his own head," and "develop good study habits." It is therefore only those who really do pay attention, use their heads, and develop at least acceptable study habits that succeed by dint of superior effort or natural ability in getting over their academic hurdles; and such a system, in effect, thus selects rather than trains good students. It is ill suited for bringing the luxury of education, like those of the electric can-opener, automatic garage doors, and armchair-controlled television, within the reach of Mr. Everyman. That is why we in the United States, in our efforts at mass education, have compromised somewhat with the old philosophy, especially in the public schools. But not enough.

For mass education is no longer a luxury from the standpoint of the society, the nation. At a time when its survival may depend upon the skill of some radar technician standing his lonely watch over complex electronic equipment on the DEW line, when the tenfold increase since World War II in the intricacy of the armed forces' equipment requires that a draftee spend half his enlistment time learning his job, when the diverse branches of science have become so sophisticated that it takes an interdisciplinary specialist to communicate among them, it is not strange that the nation is examining with cautious hope a new philosophy of instruction that promises to teach men better in a shorter time. The new philosophy reassigns the main burden of responsibility for the student's learning to the teacher. If a student has trouble it is no longer quick to conclude that he is probably lazy or isn't paying attention or has poor aptitude for the subject; it assumes, rather, that there may be something wrong with the instruction.

The changed philosophy finds its implementation in a new method, one characterized by the effort to lay out in sequence all the elemental steps by which a student can best be brought to mastery of a particular subject, to capture these on paper, tape, or film, to refine them by trial and error, and to present them to the student by mechanical devices-unconventional textbooks, simple machines costing a few dollars, or elaborate devices with some of the characteristics (and price tags) of electronic computers. Machine costs aside, however, the initial application of the method to a new subject-the development cost-is, as we shall see, high, and it is therefore logical that advanced experimentation with it can most easily be done, as most of it has been, in the large commercial enterprises and government agencies that have greater financial flexibility than the public schools and universities. The intelligence agencies, with their peculiarly high requirements for many different kinds of training, should be in the forefront of this movement.

Origins of the System

The acknowledged father of the now burgeoning innovation is Dr. B. F. Skinner, a Harvard University psychologist who had spent years in the laboratory studying how animals learn. One day, he tells us, he visited his daughter's arithmetic class and watched the teacher drill the children in their sums, some of them staring out the window, others stirring restlessly in their seats. The teacher could present only one problem at a time to the whole group and ask one child to answer. Perhaps half the class already knew the answer and needed no drill on it; and for the rest, who's to say whether any of them thought through to the answer before the unlucky one was named? In classroom drill the well prepared are bored, and the ill prepared fall, perhaps unknown to the teacher, farther and farther behind.

Dr. Skinner went home that night convinced that by applying principles he had discovered in his laboratory he could teach his daughter arithmetic a lot more efficiently than the most competent of teachers using the classroom method. In teaching a dog to touch his nose to a doorknob, for example, he had shaped the dog's behavior by rewarding him first for the roughest approximation of the act and then refining his performance in successive trials until the animal did exactly as desired. The trick could be taught in this way in a matter of minutes. Using this and other learning principles, Dr. Skinner had within a few days devised the first modern teaching machine.

Through a small window the new machine presented a bit of information which the child would be fully prepared to understand and asked a question to verify his understanding, for example:

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Just as 1+2=3, so
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2+1=____________

The child would respond by writing the sum in the blank and would then advance the machine by turning a knob. This would put his written answer under glass, where he could still see it but not change it, and at the same time expose the correct answer to check his work. If it was right, he would then advance the machine to the next problem.

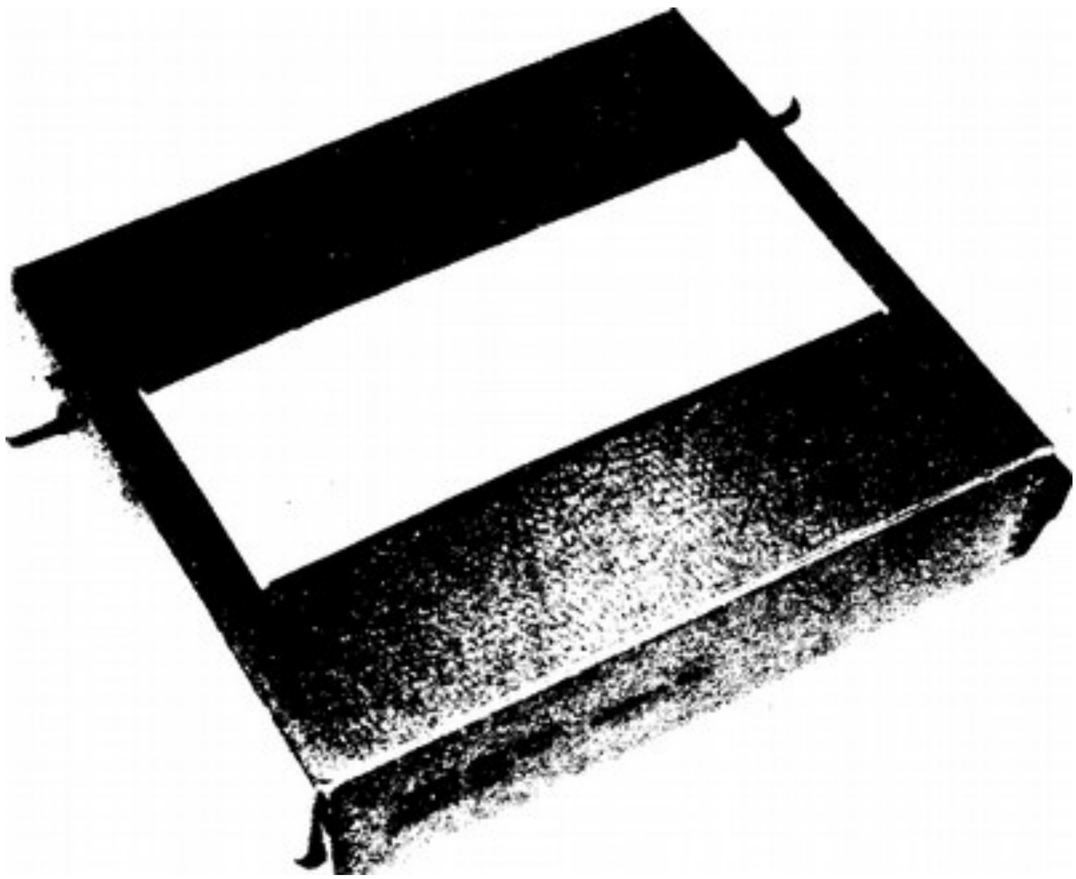

FIGURE 1. Simple Skinnerian-type machine. Book-sized, it is priced

at $5.

The series of problems framed by the machine constitute what has become known as a program, in which hundreds of frames present the material to be learned in very small steps, starting with what is familiar and introducing new information in morsels that can be readily digested, building upon these in turn and interlacing all until the student has a thorough understanding of the subject matter, its details and their interrelationships, however complex they may be. Because each step is small, he rarely makes mistakes, and he has constant assurance that he is mastering the material. And since the machine is neither in any particular hurry nor waiting for others to catch up, he can work his way through the program as fast or slowly as he likes.

Since 1958, when Dr. Skinner published an article in "Science" which aroused the first wide interest in auto-instructional methods, hundreds of businesses have experimented with programs and teaching machines, hundreds of thousands of dollars have been invested in the design and production of automatic teaching devices, and hundreds of programs-some for courses covering an entire academic year-have either been published or placed in development. Programmed instruction has been hailed as the first educational breakthrough since the invention of the textbook two hundred years ago, and there's hardly a responsible training director anywhere who isn't following closely its rapid evolution.

Programming

Instructional programming has sometimes been described as an attempt to apply the science of learning to the art of teaching. Psychologists in their laboratories have for years been developing the science of learning, but this work has been analytical, studying separate aspects of the process rather than synthesizing the whole for practical application. A good program writer not only has to observe the psychological principles that call for the presentation of a single step at a time, student participation, and immediate "reinforcement" by verification; he must also know how to break the subject down into small steps, order them properly, provide enough cues to give the student a good chance of getting the right answer but not so many as to bore him, introduce just the right number of review items and at the right intervals, lead the student to integrate the items he has learned, and gradually wean him from prompts until he is doing what he is being trained to do all on his own. Thus far the experimental laboratory has done little to provide guidelines for the programmer.

The program, however, is susceptible of empirical testing and corresponding adjustment, and in this capacity for self improvement seems to lie the reason for the dramatic successes scored by the embryonic art. Once a program has been written, regardless how crude it is, it can be tried out on a student. As the student hesitates, becomes confused, and makes errors, the writer can trace the trouble to ambiguities and other faults in his program, clear these up, and try it out again on another student. Experience has been that about six such shake-downs are usually required to weed out the major instructional errors. Then the program can be tried on groups of students and improved and refined by revision after each trial. In this way programs which teach the same material in half the time of conventional instruction have been developed.

At first almost all programs were of the Skinnerian kind, now called "linear," described above, but recently an increasing number of another type, called "branching," are being written. This type, presenting a larger unit of information in one step than the linear, tests the student by having him select the right answer to a question from among several that reflect common misunderstandings. If he chooses correctly, his answer is confirmed and he proceeds to the next unit; if not, he may be "branched" to a whole sub-sequence of frames designed to remedy the lack of understanding indicated by his particular wrong choice before coming back to this point for another try. Whereas the linear program minimizes student difficulties by keeping the steps small, the faster branching type diagnoses them as they occur and provides additional help to those who need it.

Results

The effectiveness of programmed instruction can be illustrated in the results of two studies, one for a linear and one for a branching program, typical of the many that have been carried out. At IBM a psychologist and a subject-matter expert spent six or seven months programming the first fifteen hours of a sixteen-week course in maintenance of the 7070 Data Processing System, an enormously complex electronic device. During a series of classes the work of 70 trainees who were given the programmed materials was compared with that of 42 others who had been taught by the usual lecture discussion method. The results all favored programmed instruction. None of the 70 took longer to complete the programmed materials than the 15 hours required of everyone who had the conventional instruction, and the average was about 10 hours, saving a third of the class presentation time. In an achievement test the programmed group earned an average score of 94 against 87 for the conventionally taught group, and 67% scored 95 or above, as against only 12% of the others. The students also had a favorable attitude toward the new type of instruction, 87% preferring it to the conventional and all of them recognizing that it was more effective.

FIGURE 2. Machine for miniaturized multiple-choice branching program. $1250.

The most ambitious try-out of programmed instruction to date is being made at Keesler Air Force Base, the main electronics training center of the Air Training Command. There most of the 13-week course in basic electronics principles is being programmed in the branching style and the work of matched groups of students taught exclusively by machine and by the old method are being compared. In the studies made so far the experimental students have all taken less time than that allotted for the presentation of the material in the conventional class, averaging perhaps two-thirds of this. In mastery of the subject, as measured by an 80% written, 20% practical final examination and by performance in advanced work, there seems so far to be no distinction between the experimental group and the others.

Other studies have reported similar results. Time savings have varied from ten to fifty percent. In quality either no difference has been detected or, more typically, the programmed instruction has been found the better. Almost all studies have reported varying degrees of enthusiasm and preference for the new method among the students.

Problems

The main obstacle to the use of programmed instruction is the cost of preparing the programs. Very few ready-made programs are on the market so far, and standardized programs would in any case not do for many training activities, especially in intelligence, that have their own peculiar problems. A training director can expect to pay a contractor about $1,000 per hour of programmed instruction for development alone, in addition to the cost of reproducing the usually bulky materials and of whatever machines he decides to use. In-house staffs might do the programming, but it would take at least a month to train a programmer and one to four weeks of his time to prepare each hour of instruction.

Although the initial cost is high, however, the operating costs are usually insignificant compared with those of conventional instruction. Once the programmed materials have been developed and reproduced, the only major expense is for keeping them up to date. A ten-hour course that costs $10,000 for development, $4,000 for printing, and $100 a month for up-dating, if spread over 1,000 students in a year's time, will amount to only about $15 per student. Moreover, when student employees take less time to learn, there is an extra bonus in their salaries for the time saved, not to mention the overhead for the classrooms and the instructors' salaries. Travel costs may also be reduced or even eliminated by sending instructional materials to the field instead of bringing the student to headquarters.

At Keesler AFB, for example, the Air Force is spending a substantial $165,000 for developing approximately 13 weeks of machine instruction. But this instruction, which can now be duplicated and sent almost anywhere, will have a development cost of only one dollar per student hour if as many as 410 students take the course. Thus programming promises to reduce costs when the training is to be offered a sufficient number of students and when the subject matter does not require frequent up-dating.

There are other problems of a management kind that a training director will encounter in introducing programmed instruction-its impact on his instructors, who may be apprehensive about technological unemployment and in any case will have to adapt themselves to a new role with the students; its impact on students, a few of whom may feel ill at ease with machines and for the brightest of whom even the branching program may be too slow and boring; its effect on enrollments in voluntary training and correspondence courses; the best way to begin trying out programmed materials; whether and how the self-tutoring materials can be integrated into a regular course. So far there is little experience to guide him on any of these questions.

One problem about which there is current controversy is whether it is preferable to adopt the programming principle without using a machine. The principal purposes of the machine are to prevent the student from seeing the answer until he has come up with his own solution and to keep score of his errors. If the instructor is willing to sacrifice rigor in these respects, he can give the student a specially arranged textbook in either of two forms. In the "programmed text" for linear programs the student must turn a page to see the correct answer at each small step; he is expected to discipline himself to write down his answer before he turns the page. The "scrambled book" for the branching type of program presents each new segment of information, a question, and multiple-choice answers on a single page and refers the student to a different page according to the choice he makes.

Proponents of the machine point out that it not only prevents peeking but gives the instructor dependable measures of student progress, enabling him to test as well as to teach. With miniaturization it provides much more training capacity per unit weight of programmed materials, they say, greatly reduces the cost of reproducing the materials, and adds a certain fascination to the process of learning. Recently the Air Force Academy bought 50 machines costing more than $1,000 each for use in programming a large share of its academic courses. Experimenters at Recordak Corporation have developed an elaborate and highly flexible device which they are trying out with apparent success in a great many of the parent Eastman Kodak Company's training programs.

Advocates of the programmed text, on the other hand, point to several studies which appear to establish an advantage in speed and convenience for their simpler device. A textbook can be easily carried about and used anywhere, has no moving parts to jam or bewilder the inexperienced, and can be reproduced easily on a ditto machine. Publishers have been quick to seize on the advantage of a vehicle that offers most of the benefits of the machine without requiring additional equipment: programmed texts in algebra, trigonometry, vocabulary, basic English, statistics, psychology, and many other subjects have been introduced to the market and have been widely sold.

Range of Application

Despite these and other problems associated with programmed learning, its advantages are sufficiently evident to have elicited serious consideration in many fields. Its range of applicability seems to be very wide: theoretically, any subject can be programmed if you can be explicit about just what you are training your student to know or be able to do. Most of the subjects taught in our schools, in industry, and in government could be programmed. The commercial researchers have experimented with courses in the technical, manufacturing, clerical, sales, and management fields. The Recordak experimenters say they have been unable to find any industrial training subject that could not be programmed.

Self-teaching materials offer a greater amount of administrative flexibility than may at first be realized. Using them, an individual isolated in some remote place could maintain his proficiency in rarely used skills or add to insufficient skills. They could be used in correspondence courses for employees too busy to attend formal classes. They could take care of excess enrollments when not enough instructors were available. They could be used to check proficiency in the prerequisites for an advanced course. By freeing an instructor of routine teaching, they could contribute significantly to his ability to keep up with his field and give students individual help. They could constitute for a training director a definitive statement of training standards. And they have been found to exercise a remarkably stimulating effect on the instructional staff, who cannot fail to be influenced by the example they set.

There seems no reason to doubt that all of these advantages carry over into training in intelligence subjects, and some times an additional advantage in the possibility of avoiding security problems by separating instructor from trainee. All that is needed to see the possibilities in intelligence training is an understanding of the nature of programmed instruction and a lively imagination. The following paragraphs suggest at random a few applications to instructional problems in this field.

Intelligence Applications: Overt

"When you go into a new job you are suddenly surrounded by the language of that job, and the initial phases of most of our orientation programs are really devoted to the language of the job. We think we might teach the terminology of an operation by programmed learning and . . . speed up the entire orientation.[1] In the intelligence community, too, self instructional materials might improve the effectiveness of our orientation courses. They could also serve, if circulated after every major revision and kept on library shelves for general reference, as a convenient means for keeping everyone up to date. One particular aspect of the orientation program, the security lecture, because its lessons must often be relearned in the school of hard knocks, might be especially important to put into programmed form. If the program were given by machine, it could guarantee that every employee had faced and solved every security problem deemed necessary, and had done so before being given any security responsibility in his agency.

In almost all administrative procedures, particularly those involving paper work, answers to the common problems have been agreed upon and the preparation of programmed materials should be easy. At Lackland Air Force Base a four-hour course in filing took only two to three hours of student time after programming. All kinds of record keeping could be programmed-accounting, inventory taking, supply procedures, fiscal systems, routing practices, and so on.

In processing the steadily increasing volume of incoming information, as the community turns more and more to standard reporting formats, common coding, and uniform dissemination procedures, there is a developing opportunity for interagency training in these procedures. They should lend themselves readily to programmed instruction, and the more trainees there were the more economical it would become.

Reference librarians find it a full-time job keeping up with the variety of publications and other documentary sources to which they guide analysts, and a new analyst may have so much thrown at him about library facilities that it takes him months to master full knowledge of his sources. Here programmed instruction, centrally prepared and continually updated for the community as a service of Common concern, could make an important contribution to the accessibility to intelligence of government-wide reference facilities.

One can only hope that eventually some of the techniques of programming may be applied with advantage to training in the interpretive skills of economic, geographic, scientific, and other kinds of analysis. At present we know too little about the processes of judgment through which an interpretive conclusion is reached to be able to teach them with precision, and explicit precision is needed if a subject is to be properly programmed. The analyst may, however, need refresher training in subjects like the manipulation of statistics and the use of the slide rule. Many such courses have been or are being programmed and will be available for self-instruction. Others that were needed could be developed.

In the communications field, subjects to which auto-instruction is applicable range from sending and receiving Morse code to the operation of a master console, from typing and teletyping to the maintenance of complex equipment. In these and many other communications jobs the behavior to be learned can be explicitly described, and it should be a simple matter to apply the insights gained from years of tutorial experience to the preparation of a trial program. From there on, a series of try-outs, followed each time by improvements in the program, should eventually produce self-instructional material of a high order of effectiveness. The branching style of programming was actually evolved in support of efforts to find an effective way to teach Air Force technicians to spot troubles in electronic equipment.

Auto-instruction in maintenance, trouble-shooting, and testing need not be limited to communications equipment. Equipment of any kind bought in quantity on the open market, no matter how complex, could be tested by a technician without special skills. Each step in the testing process could be photographed and presented by slide projector to the tester. Earphones could remind him what to do next, and the whole process could be so detailed that there would be no need for him to rely on experience or memory. Such devices are now being used with great success by the Hughes Aircraft Company to guide assemblers of electronic equipment.

It should even be possible to program the teaching of cable and report writing. Besides matters of format like the use of symbols, terminology, headings, and word order, more complex skills such as writing briefly and with a minimum of ambiguity could with a little ingenuity be programmed. The trainee would not develop an individual style, but the desideratum seems to be a highly standardized language in which the number of acceptable ways of expressing an idea is narrowly limited.

Map reading and map interpretation, in which intelligence personnel often lack proper training despite its basic importance, should offer no real obstacle to programmers. Instruction in this subject is so widely needed that its programming should rapidly pay for itself many times over.

Covert Applications

Programmed instruction might be used with particular felicity on an agent undergoing training in a safe house. Training in observation and description, for example, with little time and opportunity to practice observation, might present an almost insoluble problem. But a self-instructional program could, by gradually making the discriminations more difficult and withdrawing prompts, bring him to whatever level of accuracy in observation is desired. It should be possible to prepare programs which would improve the agent's ability to judge heights, distances, colors, textures, materials, sounds, weights, and speeds.

If it is not wished simply to improve an agent's general powers of observation but to give him a specific ability to observe and describe, say, synthetic fuel plants, airfields, or naval ordnance, he needs to be taught the critical things to look for and the words to use to describe them. Programmed instruction should be able to do this sort of training very effectively, imparting any required level of competence. A program for training agents to observe and describe people is currently under development.

Programmed instruction can be successful in teaching agent skills as well as sharpening discriminations. There is no reason, for example, why lip-reading cannot be programmed by providing life-like examples, probably short motion-picture sequences. Or it might be convenient for the agent to be able to take shorthand notes; either a simplified or a professional level skill in shorthand could be acquired by programmed instruction. As a matter of fact, it seems theoretically possible to develop through programming an ability to note down anything that may be said in any language without necessarily understanding it-a matter of recording sounds rather than meanings.

It has been shown that it is possible for a student to learn at least the basics of a foreign language through programmed instruction. One course now on the market, for example, permits the student to develop, without an instructor and at his own pace, "a clear idea of Spanish sound patterns, the ability to understand, speak, and write simple Spanish, an active vocabulary of over 500 words, and an acquaintance with the basic structural patterns of spoken Spanish." In the Army's Human Resources Research Office at George Washington University adults of average intelligence, after about four weeks of intensive study, using only tapes and programmed textual materials, acquired enough skill in speaking and understanding Russian to interrogate "prisoners of war" in that language and obtain from 85 to 97 percent of the required information. If an agent needed to develop quickly a facility, say, for understanding the common speech of a foreign country, he might be furnished programmed instruction in it.

Another kind of skill it might be desirable for an agent to have is the reading and interpretation of instruments, whether a simple pressure gauge or the master display at a regional command center. A report on self-instructional programs for SAGE system operators published last spring shows that programmed instruction is suitable for such a complex skill as track monitoring and direction finding. The SAGE operator skills include reading symbolic information on a flashing display, knowing where to reach for various buttons and switches on the console, and knowing when and under what conditions certain actions should be taken. The selfinstructional materials produced a higher level of achievement (87%) in fourteen hours than had previously been attained (81%) after more than a year on the job.

It might be worth while to program an agent's cover story. If it had to be worked out uniquely for each agent, the effort would probably not be worth the advantages; but it may be that, once a particular cover story were programmed, a number of others could be substituted, mutatis a few mutandis. The questions would largely remain the same; the answers would change. If this were true, auto-instruction for cover stories might eventually be prepared in advance and supplied as needed. At least orientive material supporting cover, like the geography, customs, and monetary practices of some country, could be programmed for thorough learning.

The equipment would not always be so elaborate as to require a safe house. Programs that teach visual discriminations or recognitions or verbal skills not including the ability to speak can usually be presented as a programmed text which the agent could use in his own quarters. Programs that teach the discrimination of moving parts, such as lipreading, or of sounds, as of engines or airplanes, must be presented by a teaching machine, presumably in a safe house; but miniaturization, together with increasingly widespread use of the machines, may eventually make it practical to put such equipment into the agent's home. Technical advances in programming hardware promise that we soon may have devices to reproduce programs quickly and inexpensively in small, easily handled packages.

The application of programmed instruction to intelligence training has only just begun. The examples above may suggest some of the possibilities, but there are undoubtedly many other ways in which this new kind of teaching can enhance our intelligence effort. In the days of crisis current and to come, the key role of intelligence gives it more need than ever to make sure that its personnel are well trained. Programmed instruction offers means of substantially improving some of our training. It is worth serious examination.

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1 Jerome P. Lysaught, Director of Training, Eastman Kodak Company, in Programmed Learning (Ann Arbor, Michigan, 1961).

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