Programmed Instruction Revisited

BY B. F. SKINNER

Teaching machines were invented to restore the important features of personalized instruction, recalls Mr. Skinner. Today, we have the technology that could enable students to profit from an immediate evaluation of what they have learned and to move forward at their own pace.

THE PUBLIC SCHOOL was invented to bring the services of a private tutor to more than one student at a time. As the number of students increased, however, each student necessarily received less attention. By the time the number had reached 25 or 30, personal attention had become sporadic. Textbooks were invented to take over some of the work of the tutor, but two problems remained unsolved. What is done simultaneously by every member of a large group cannot be evaluated immediately, and what is taught to a large group cannot be precisely what each student is ready just at that moment to learn. Teaching machines were invented to restore these important features of personal instruction.

A BRIEF HISTORY

More than 50 years ago Sidney Pressey, a professor at Ohio State University, hailed "the coming 'industrial revolution' in education."[1] In 1926 Pressey had described a machine that "tests and also teaches" (illustration, this page). A student studied a subject in the usual way and then turned to the machine. It directed the student to the first item on a multiple-choice test, and the student made a choice by pressing a numbered key. If the choice was right, the machine moved on to the next item; if the choice was wrong, the student pressed another key. When the student went through a test a second time, the machine stopped only on those items on

Pressey's machine that "tests and also teaches."

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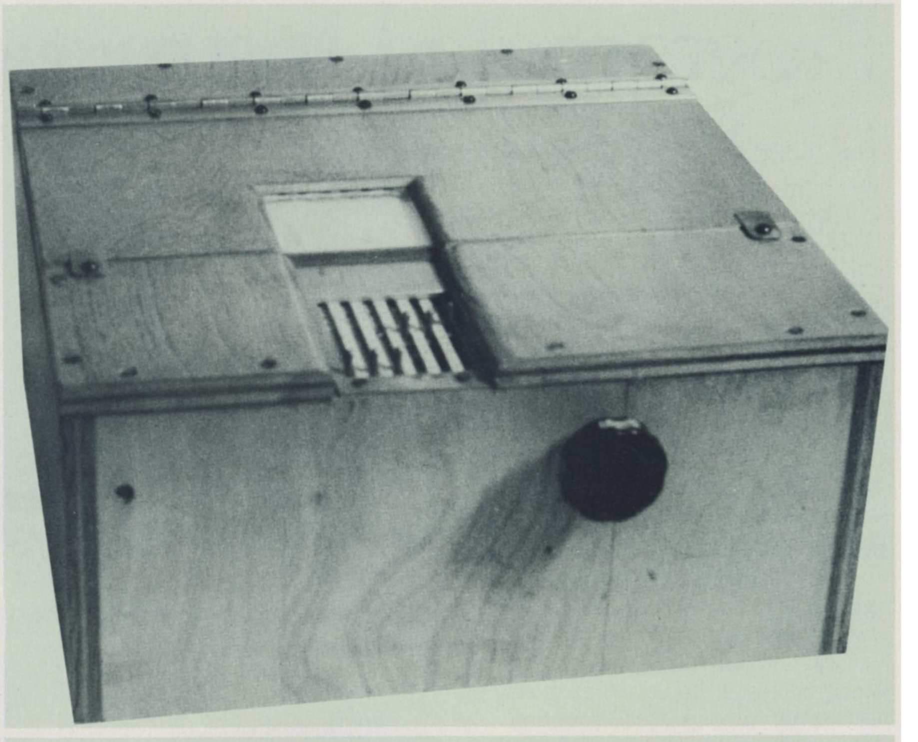
Photo by William O. Seymour

which the student's first choice had been wrong.

I had not heard of Pressey's work when, at a meeting at the University of Pittsburgh in 1954, I demonstrated a machine designed to teach arithmetic (photo on this page). In that machine, a strip of paper passes from one side of the box to the other, exposing a square section on which a problem is printed. Small holes are punched in the paper, and the student causes numerals to show through these holes by moving sliders. The student then tests what he or she has done by turning a knob on the front of the box. If the student has solved the problem correctly, a new problem moves into place; if the answer is wrong, the student must reset the sliders. (The photo on page 106 shows a more sophisticated version of this machine, which IBM made for me a few years later. It has more sliders, and it has letters as well as numerals.) A recent advertisement for a home computer showed a young girl solving a problem in arithmetic in much the same way, except that she was pressing keys.



Machine to teach arithmetic demonstrated at the University of Pittsburgh, 1954.

My machine differed from Pressey's in several important ways. First, students came to my machine without having studied any special material beforehand; they were being taught, not tested. Second, and more important, the students composed their responses instead of choosing them. That is the difference between, say, having a reading knowledge and having a speaking knowledge of a second language. One can make an excellent score on a multiple-choice test of a second language even when one cannot speak the language well. There is a similar (but less obvious) difference between "reading mathematics" and "speaking mathematics" – the difference most of us once felt when we followed easily enough as the author of a text solved a sample problem and then stumbled when we tried to solve similar problems by ourselves. The third, and perhaps the most important, difference was that Pressey's machine simply gave an immediate evaluation of each response, whereas in my machine the items were arranged in a special sequence, so that, after completing the material in frame 1, the students were better able to tackle frame 2, and their behavior became steadily more effective as they passed from frame to frame. I began to speak of "programmed instruction."[2]

Composing answers by moving sliders might have been good enough for simple arithmetic or spelling, but it was too slow and awkward for most of the things I wanted to teach. So I designed a different machine (see page 107), which had 30 frames of a program printed radially on a large disk. A single frame appeared in an opening in the machine. The student wrote a response on a strip of paper in another opening. By lifting a lever, the student then moved what had been written under a transparent cover, where it could not be changed, and uncovered the correct response. In 1958 a dozen of these machines were placed in a self-instruction room in Sever Hall in the Harvard Yard (see page 108) for use in my course, Natural Sciences 114. James Holland and I wrote the program, which was eventually published in workbook form.[3] The first of about 2,300 items reads, "A doctor taps your knee (patellar tendon) with a rubber hammer to test your ______," and the student writes "reflexes."

That sort of thing can also be done more conveniently with computers, of course. The machines I have described are museum pieces, and – appropriately enough – all of them are now housed in the Smithsonian.

THE TEACHING MACHINE MOVEMENT

I was soon saying that, with the help of teaching machines and programmed instruction, students could learn twice as much in the same time and with the same effort as in a standard classroom. Other kinds of machines soon appeared. In some of them the responses were chosen, as in Pressey's machine; in others the responses were composed, as in mine. Great numbers of programs were written. Most of them were published in workbook form, with correct answers hidden beneath a sliding mask or found on another page. By the end of 1962, according to an editorial in *Science*, 250 programmed courses would be available in elementary, secondary, and college mathematics; 60, in science; 25, in electronics and engineering; 25, in foreign languages; and 120, in social studies. Many of these courses were excellent. A colleague once told me that he had decided that he ought to know more about biochemistry, so he had bought a programmed text. "It was amazing!" he said. "In a week I knew biochemistry!" He did not mean that he was then a biochemist, of course, but he had learned a great deal in a remarkably short period of time with very little effort.

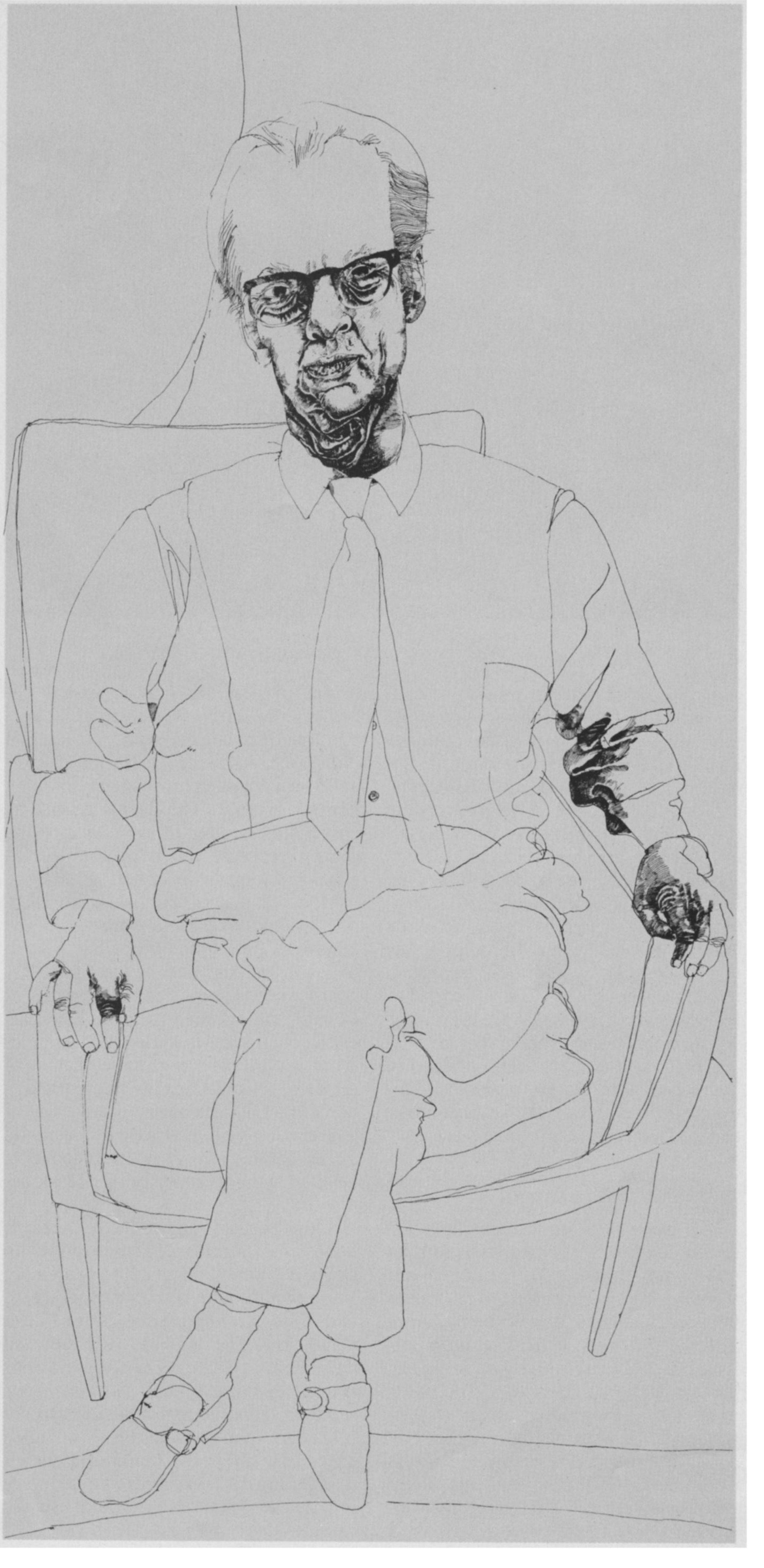
Photo by Will Rapport

Programmed instruction, with or without machines, was quickly adopted by industry, but the education establishment was not impressed. It was as if the automobile industry had been shown how to build cars in half the time at half the cost and had said, "No." There were reasons for this, of course. The machines were crude, the programs were untested, and there were no ready standards of comparison. Teaching machines would have cost money that was not budgeted. Teachers misunderstood the role of the machines and were fearful of losing their jobs. Nor did a consensus in favor of adopting these machines exist among administrators, school boards, and parents.

Two administrative problems would have created even more serious trouble. What would happen if students really learned twice as fast? If first-grade students covered second-grade material as well, what would the second-grade teacher do? How soon would students enter the job market? That problem could have been solved by teaching many other things – surely a happy solution, but one that would have required the retraining of teachers, the restocking of libraries and storerooms, and many other changes. Even more disruptive would have been the inevitable abandonment of the phalanx system. If each student could advance at his or her own pace, how were students to be grouped? What would happen to the homeroom?

It would be unfair to say that teaching machines and programmed instruction were not adopted more quickly simply because improving education would cause too much trouble. A more likely obstacle was a failure to understand the principles on which they were based. A change was needed in "educational psychology," but this need was obscured by an event that occurred at about the same time: the Russians put Sputnik I into orbit. Americans were stunned. How could the Russians have beaten us into outer space? Something must be wrong with American education.

Congress quickly passed the National Defense Education Act, and money was made available to improve teaching, especially in the areas of science and mathematics. A group of educators met at Woods Hole to plan the use of these funds. Jerome Bruner reported the group's recommendations in his book, *The Process of Education*, which be-



Portrait of B.F. Skinner from life by Alan E. Cober, December 1971, New York City.

Machine to teach arithmetic and spelling built by IBM, 1958.

came a kind of bible in schools of education. Students were no longer to be told things; they were to discover things for themselves. They were not to memorize, but to think, grasp concepts, explore, be creative. Vast sums were spent on the development of materials to improve science teaching in high schools. Moreover, students would no longer add, subtract, multiply, and divide (hand calculators could do those things); instead, with the help of the new math, they would think as mathematicians thought. Twenty-five years later, however, students' grades in high school science and mathematics were, if anything, a little worse. Those who had developed the materials blamed the teachers, but it was the teachers who had needed help in the first place.

TEACHING AND LEARNING

The cognitive movement that followed Sputnik I seemed to legitimize traditional theories of teaching and learning. Many educators were content with such books as William James' *Talks to Teachers*, which had been published in 1899 and which was written in the language of the layperson. Programmed instruction, by contrast, took advantage of what had been discovered about teaching and learning in a special discipline called the experimental analysis of behavior. My first programs were written when I was finishing an application of that analysis to verbal behavior.[4] By carefully constructing certain "contingencies of reinforcement," it is possible to change behavior quickly and to maintain it in strength for long periods of time. The details cannot be covered here, but I can illustrate the central process, called operant conditioning, by means of a story.

Many years ago I published an article titled "How to Teach Animals."[5] The editors of *Look* found my article hard to believe, and they challenged me. If I could teach an animal as swiftly as I said I could, they wanted pictures. I accepted the challenge. I would teach a dog to stand on its hind legs in a matter of minutes. I would neither touch the dog nor attract its attention in any way. I would not give it any reason to stand up (as by holding a piece of meat above its head). I would simply reinforce its behavior.

Some preparation would be needed, however. A reinforcer is most powerful when it follows behavior very quickly – optimally, within a fraction of a second. Giving a hungry dog a bit of meat is too slow. The dog has to see the meat and come and get it, and these things take time. For essentially instantaneous reinforcement, a conditioned reinforcer is needed. In my article, I had explained how to condition the sound of a clicker as a reinforcer. But, since we were going to take pictures, I would use the camera flash instead. The *Look* staff members were to buy a dog and give it its daily ration in the following way: when the dog was moving about the room, they were to operate the flash and then give the dog a bit of meat. It would soon respond to the flash by coming to be fed – and when, after a day or two, it did so instantly, I would take over.

When I saw the dog for the first time, I took the switch that operated the flash and told the photographer to keep his camera on the dog. I had put some horizontal lines on one wall of the room, and, when the dog went near them, I flashed the light. It came to the *Look* reporter to be fed and then went back near the lines – predictably, because I had just reinforced going there. Sighting across the dog's head, I chose a line somewhat above its normal position and reinforced the first movement that brought the head to that height. When the dog returned from being fed, an effect was clear: the animal was holding its head noticeably higher, and I could then choose a higher line. As I moved upward from line to line, the dog's forefeet began to come off the floor, and it was soon standing straight up. Q.E.D. Since there was still some meat left, I continued this "differential reinforcement" until the dog was *leaping* straight up, its hindfeet nearly a foot off the floor. A picture had been taken with each flash, and *Look* published one showing the final spectacular leap.

You will not find a correct account of the kind of thing I did with the dog in most introductory psychology textbooks. Some of them would say that I rewarded the dog for jumping. As the etymology shows, however, a reward is compensation or remuneration for services performed and is seldom immediately contingent on behavior. We reward people; we *reinforce* behavior. Other texts would say that the dog learned by trial and error. But the dog was not *trying* to do anything when it lifted its head, and it certainly did not learn anything from errors. Some texts would call lifting the head or standing up purposive or goal-directed behavior, but a goal has no effect on the behavior through which it is reached. Only past consequences have any effect.

TEACHING OR TRAINING?

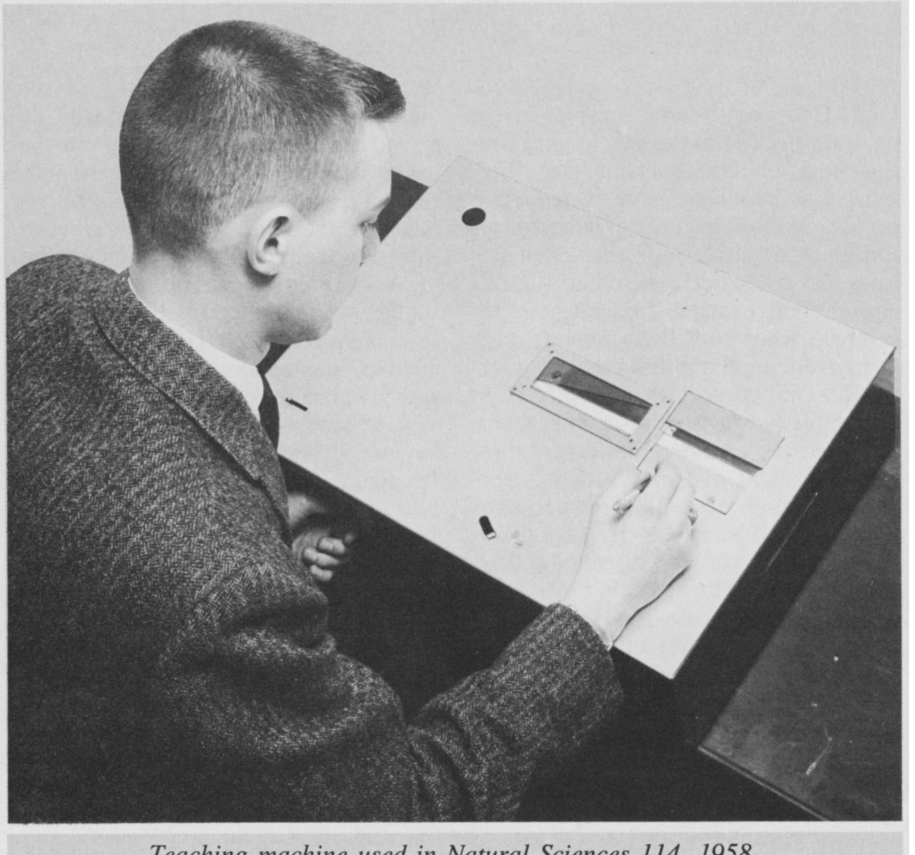
Many educators would say that what I did with the dog was training, not teaching. If so, it was very much improved training. Dogs have been trained for centuries, and there are useful rules of thumb, but it is highly unlikely that even the most expert animal trainer could have brought about that much change in behavior in such a short time by conventional means. Teaching is more than training, but it uses the same behavioral processes.

Of course, we seldom teach in just that way. We do not teach a child to tie a knot by conditioning a reinforcer, giving the child two pieces of string, and then reinforcing any move that contributes to the fashioning of a knot. Instead, we *show* the child how to tie a knot; we model the behavior, and the child imitates us. But why should the child do so?

Before we can show the child how to tie a knot, he or she must have learned to imitate, and that learning will have taken place through operant conditioning. Because the vocal musculature of the human species has come under operant control, we can also *tell* the child how to tie a knot, and in that case the need for an acquired operant repertoire is even more obvious.

Showing and telling are ways of "priming" behavior, of getting people to behave in a given way for the first time so that the behavior can be reinforced. We do not learn by imitating, however, or because we are told what to do. Consequences must follow. Consider how most of us learned to drive a car. At first, we turned the starting switch when we saw our instructor do so, we pressed the brake pedal when he or she said "press," and so on. But the moves we made had consequences. When we turned the switch, the engine started; when we pressed the brake pedal, the car slowed or stopped. Those were natural consequences, and they were more closely contingent on our behavior than were those flashes on the behavior of the dog. They eventually shaped skillful driving. As long as we were responding to instruction, the car moved but we were not driving it. We learned "how to drive," in the sense of driving well, only when the contingencies of reinforcement maintained by the car took over. We do not learn by doing, as Aristotle maintained; we learn when what we do has reinforcing consequences. To teach is to arrange such consequences.

The same two stages occur in learning to talk about things. Someone primes our behavior either by saying something that we repeat or by writing something that we read. When reinforcing consequences follow, we learn. For a time, our behavior may need to be "prompted." As it gains in strength, however, the prompts can be withdrawn or "vanished," in the sense in which a magician "vanishes" a bouquet of flowers.



Teaching machine used in Natural Sciences 114, 1958.

The roles of priming, prompting, and vanishing are especially clear in teaching or learning a poem. My daughter Deborah once came home from school complaining that she had been assigned to learn 15 lines of Longfellow's "Evangeline." ("Those are very long lines," she said.) I told her I would show her how she could learn them quite easily. I wrote the lines on a chalkboard and asked her to read them. Then I erased a few words and asked her to read them again. She did so correctly in spite of the omissions. I erased a few more words, and she could still "read" them. After five or six erasures, she "read" them although there was nothing on the chalkboard. At first, the words were primes. By reading them, she engaged in the required behavior – but not yet for the right reasons. The words I left on the chalkboard functioned as slowly vanishing prompts. We do something of the same sort when we learn a poem by ourselves. We prime our behavior by reading a line, and then we turn away from the text and say as much of the line as we can, looking back and prompting ourselves if necessary. By looking back less and less often, we slowly vanish the prompts.

We refer to the same two stages when we say that education is preparation. "Preparation for life" was once the phrase. Teachers often forget, however, that preparing is not the same as living. The consequences that induce students to come to school, listen to their teachers, watch demonstrations, study, and answer questions are not the consequences that will follow when they use what they have learned. Learning to drive a car is not driving, memorizing is not reciting, and learning to read is not reading. Students and teachers tend to move too quickly to the "living" stage. The student who wishes to be a violinist or a tennis player usually wants to play too soon. Likewise, students who demand the right to choose what they will study are usually trying to skip the instructional stage. Those who criticize programmed instruction by saying that

Self-instruction room in the Harvard Yard, 1958.

students should learn to read *real* books also want to move out of the preparation stage too quickly.

MOTIVATION

For thousands of years students studied because they were beaten when they did not do so. The cane and the rod were the tools of the teaching profession. Unfortunately, they have not yet been fully replaced. Much of the time students still study to avoid the consequences of not studying. The standard by-products of punitive control – truancy or dropping out, vandalism, and apathy – are all too evident. Obviously, it has been hard to find positive alternatives. Passing grades, promotion, scholarships contingent on grades, diplomas, prizes, and awards – if reinforcing at all – are not effectively contingent on behavior. Nor has it been possible to make the reinforcers of daily life contingent on much of what is to be taught, for example, the "basics."

The primary reinforcer in programmed instruction is of a special kind. Contingencies of survival in the natural selection of the species and contingencies of reinforcement in the lifetime of an individual have made certain immediate consequences of behavior reinforcing, regardless of what then follows of biological or other significance. For example, pushing is reinforced when something moves, quite apart from anything that happens afterward. The immediate effect has acquired the power to reinforce because a great variety of other reinforcers have followed it. Good instructional programs maximize the effect of success as a conditioned reinforcer by asking students to take very small steps and by making every effort to help them do so successfully. Success is perhaps not a very powerful reinforcer, but it has a powerful effect when properly scheduled and when successful responses fortunately occur on what is called a variable-ratio schedule – the powerful schedule at the heart of all gambling systems.

A similar solution is not available in the classroom because of the basic faults that programmed instruction was designed to correct: only rarely can behavior be immediately reinforced, and a student cannot move on at once to new material. Hence teachers must resort to some kind of punishment. Such a return to aversive contingencies may be very subtle. A Committee for Economic Development complained that "an alarming number of students leave high school with the idea that the adult world tolerates tardiness, absences, and misbehavior."[6] The committee called for "stringent education standards and tough discipline." "Discipline" has come a long way from its original association with "disciple"; it now means "punishment," which, in turn, means more dropouts and more vandalism. The committee seemed to be aware of that and added that it wanted to "encourage maximum creativity on how these standards are achieved." In other words, the committee did not know how to achieve them. To return to punitive control is to admit that we have failed to solve a central problem in education.

Correct responses and signs of prog-

Photo by Will Rapport

ress are the kinds of reinforcers most appropriate to instruction as preparation, but other reinforcers must follow if there is any point in teaching. The reinforcers immediately affecting Deborah's behavior as she learned those 15 lines of poetry were probably negative. She was successfully fulfilling an assignment. (She may have gained a measure of positive social reinforcement a month later when, as she reported, she was the only one in her class who could still remember the 15 lines – but that was too late to help in the preparation stage.) If she ever recited the lines to herself for pleasure, the reinforcers were those that Longfellow put into his poem. Those are the kinds of reinforcers that are at work when, if you happen to like poetry, you memorize a poem and then recite it to yourself. While you are memorizing, however, the effective reinforcing consequence is getting the right words out. If you are composing a poem, your behavior may be reinforced in both ways: a line comes out right (and scans and rhymes, if it is that kind of poem), and the line says something you find pleasing or even beautiful.

The same thing happens in writing prose. People are said to write articles or books for money or acclaim. Those may be rewards, but they do not occur soon enough to be reinforcers. At one's desk the reinforcers are the appearances of sentences that make sense, clear up puzzles, answer questions, make points. Instructional programs in which students complete sentences, rather than select them from a set of multiple choices, have that same effect. Someone once said that programs that have blanks to be filled are like Swiss cheese, full of holes, but when students fill the holes with the right words, something happens that is very much like what happens when they use what they have learned. When we are writing a difficult paper and just the right word comes, a hole is filled and our behavior is reinforced.

It is sometimes said that programmed instruction gives too much help, that it does not "challenge" the student. But no amount of help is too much in the preparation stage. It must vanish, of course, as other reinforcers take over. The more helpful the program, the more (and more easily) the student learns. Some 350 years ago Comenius said, "The more the teacher teaches the *less* the student learns," but that is true only if it means "the less the student learns about learning." Some students profit from bad teaching because they learn how to teach themselves, but good teachers certainly have their place. How to study is a separate skill, and it can be taught, possibly by a program designed to do so.

THE PROBLEM OF ATTENTION

The preparation stage of teaching raises a standard problem. Teachers cannot teach unless students pay attention. Students who "want an education" may pay attention for unidentified reasons, but what can be done with the others? Physical restraint is one solution, albeit a crude one. A teacher in a small private school once boasted that, to keep her students from looking out the window, she simply held her classes in a room without windows. In essence, she put blinders on her students. In the heyday of the teaching machine movement, a machine was advertised that held the student's head between earphones, confronting a brightly lighted page. The machine forced students to hear and see. Unfortunately, it did not teach them how to listen or look.

The threat of punishment falls short of physical restraint. Few words are spoken by teachers more often than, "Pay attention!" And these words are usually spoken with all the authority of "*Achtung*!" or "Now hear this!" Teachers who have relinquished the power to punish must resort to a pathetic personal appeal: "*Please* pay attention."

A third possibility is to attract attention. Television advertising has probably exhausted the possibilities. The creators of television advertising assume that people attend to anything that is loud, bright, colorful, endearing, amusing, sudden, strange, or puzzling – or that they will do so at least once, if they are exposed to it many times. Textbooks are often constructed on similar principles, involving the use of colored pictures and intriguing titles and subtitles. Unfortunately, such textbooks have a basic fault: they do not teach students to pay attention to unattractive things. Computers have made it altogether too easy to attract the attention of students, and the need to teach students to pay attention is often neglected, as Julie Vargas has pointed out.[7]

Students pay attention when doing so has reinforcing consequences. Compare a typical classroom with a roomful of bingo players. No one tells bingo players to pay attention, nor are the cards or counters made particularly attractive. The players look and listen carefully for a very good reason: reinforcing consequences follow only when they do so. Well-constructed programs have the same effect. Children who are said to have a short attention span will watch a western on television without taking their eyes off the screen. A book that is not attractive as an object will hold the reader if the writer has filled it with reinforcing things.

APPRECIATION

Not everything we want to teach can be programmed, but contrived reinforcing contingencies are still useful in the preparation stage. How, for example, can we teach the appreciation of art, music, or literature? Perhaps another story will be helpful.

In the early Fifties two of my students came to me with a problem. They owned several good pieces of modern art with which they had decorated their room, but they had now acquired a roommate who wanted to put a Harvard banner on the wall and a sports trophy or two on the mantelpiece. That would spoil the atmosphere. Did I see any reason why they should not use some of the techniques I had described in my course to teach their roommate to enjoy modern art? I told them I saw no objection, provided they agreed to tell the roommate afterward what they had done.

They began by paying little or no attention to him unless he asked about their paintings or sculptures. They gave a party and bribed a young woman to ask the roommate about these art objects and to hang on his every word. They sent his name to Boston galleries, and he began to receive announcements of shows. A month later they reported some progress: the roommate had asked them to go with him to the Boston Museum of Fine Arts. They went, and when they saw him looking at a picture that he seemed especially to like, they dropped a $5 bill on the floor. He looked down and found the bill. Before another month had passed, they came to show me the first modern painting purchased by their roommate.

Recently, I learned that one of the students was living in New York City, and I phoned to ask him about the project. Had they ever told their roommate what they had done? No, he was sorry, they had not. What had happened to the roommate? He was not sure, but he had run across him recently in the Museum of Modern Art! Perhaps my students had no right to intervene in the life of their roommate in that fashion. I think they should at least have told him what they had done. But they had taught him to enjoy modern art, and he was apparently still enjoying it 30 years later. Of course, they had used irrelevant reinforcers. Art is not something worth knowing about simply because you can talk about it to attractive people or find money on the floor of a museum. But that was part of the preparation stage. The paintings and sculptures took over soon enough.

Suppose the roommate had been required to take a course in art appreciation – or had taken one as a "gut" course in order to remain eligible for a team. How would the instructor have induced him to look at paintings until the reinforcers that the artists put into them had their effect? Traditionally, the instructor would have asked him to answer questions about artists, schools of art, periods, subjects, theories, and so on. Answering those questions would have had little more to do with the *enjoyment* of art than the reinforcers my students used. And suppose the instructor had run across such an unwilling student 30 years later in a museum of art. Would he not have been pleased that his teaching had been so successful?

Consequences that are possibly irrelevant must also be used to induce students to read books and to listen to music, until the very different consequences that writers put into their books and that composers and performers put into their music can have their effect. These are the consequences that are eventually "appreciated."

"Reading skills are very important. That's how you find out what's going to be on TV."

DISCOVERY AND CREATIVITY

Teachers also go too far in trying to make the preparation stage of learning resemble daily life when, rather than tell students the facts of science, they ask students to discover these facts for themselves. That is how scientists go about their work in the real world, and what is learned in this manner is no doubt a more genuine kind of knowledge. But using apparatus and methods prescribed by a teacher is not really making a discovery. Indeed, this process is not very different from "discovering" the facts of science in a textbook. The discovery approach may help students enjoy "a sense of what learning is all about," and they may find experimenting more interesting than reading, but it is impossible to learn very much science in this way. Only by designing their own apparatus and working out their own methods will students learn much about making discoveries, and that is very rarely done. Good research practice is a subject in its own right, to be taught as such.

It is also a mistake to try to make the preparation stage "creative." A recent article in *Science* reported that only 10% of all scientists had done creative work, a fact that the author explained by saying that only 10% of scientists "possessed creativity." It would be much more important to know how they were said to acquire creativity. People who discover or create are behaving in ways that – by definition – cannot have been taught. But preparing to discover or create is feasible. The key word in Darwin's title was "origin." The origin of millions of species was to be found not in an act of creation, but in the selection of otherwise unrelated variations. Truly creative individuals, if any exist at all, behave in ways that are selected by reinforcement, but variations must occur to be selected. Some variations may be accidental, but students can learn to increase the number and, in that sense, to be more creative. Like all the creative people of the past, however, they must first be taught something to be creative *with*.

Education is primarily concerned with the transmission of the culture, and that means the transmission of what is already known. Educators have turned to discovery and creativity in an effort to interest their students, but good contingencies of reinforcement do that in a much more profitable way.

THE FUTURE

The small computer is the ideal hardware for programmed instruction. It is not functioning as a computer, of course; it is teaching. It should be called a teaching machine. We have flying machines, sewing machines, and calculating machines – and a machine that teaches by arranging contingencies of reinforcement is a teaching machine. When computers were first used as teaching machines, their sponsors began to speak of "computer-aided instruction." That terminology is correct if teachers merely use computers to help them teach, but it is wrong when the computer does it all. We do not speak of computer-aided calculation. We use a calculating machine.

With the help of teaching machines and instructional programs, schools can be designed so that students will profit from an immediate evaluation of what they have done and will move forward as soon as they are ready. Those who move quickly will cover many more fields, some of them possibly beyond the range of available teachers. Those who move slowly will survive as successful students. Teachers will have more time to talk with their students, and students will learn to express themselves more effectively. (Students will have a great deal more to express, as well.) Teachers will have more time to get to know students and to serve as counselors. They will have more to show for their work, and teaching will become an honored and generously rewarded profession. Because education will be much more efficient, it will probably cost less than it does now. This is not a utopian dream. It is well within range of an existing technology of teaching.

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2. B. F. Skinner, "The Science of Learning and the Art of Teaching," *Harvard Educational Review*, vol. 24, 1954, pp. 86-97.
3. James G. Holland and B. F. Skinner, *The Analysis of Behavior* (New York: McGraw-Hill, 1961).
4. B. F. Skinner, *Verbal Behavior* (New York: Appleton-Century-Crofts, 1957).
5. B. F. Skinner, "How to Teach Animals," *Scientific American*, December 1951, pp. 26-29.
6. *New York Times*, 6 September 1985.
7. Julie S. Vargas, "Instructional Design Flaws in Computer-Assisted Instruction," *Phi Delta Kappan*, June 1986, pp. 738-44. K