coAction / FOURTH QUARTER 1988

Milestones in Early Learning Devices

By 1936, over 600 inventions had been patented as educational aids. One device rewarded students with candy lozenges for correct answers. Other students marked "chemosheets" with a dampened swab; correct answers turned blue, incorrect answers turned red. Not surprisingly, most programmed learning devices never caught on. But as this pioneer in computer-assisted instruction shows, these early devices laid the groundwork for computerized instruction of today.

BY JESSE M. HEINES

Dr. Jesse M. Heines is assistant professor of computer science at the University of Lowell. Dr. Heines provides consultation and authoring workshops on computer-based training and design, and is the author of Screen Design Strategies for Computer-Assisted Instruction.

I was both honored and concerned when Authorware asked me to contribute an article to the premiere issue of *CoAction*. Honored because I see *Course of Action* as a milestone in the development of an easy-to-use yet powerful computer-based instruction system. Concerned because I fear many people using such a sophisticated system may become so enthralled by its features that they lose sight of the educational needs that the system was designed to meet. That's why this kick-off issue seems a good time to reflect on our roots and consider the history of the development of learning tools in classroom instruction. Consequently, this first article takes a look back at the milestones in early learning devices that have contributed to today's state-of-the-art computerized classroom instruction. I think the journey is worth taking if we are to understand the possibilities of computer-based instruction systems of today, as well as how far such systems have actually come.

THORNDIKE'S MIRACLE

Edward L. Thorndike set the theoretical stage for mechanized learning devices in 1912 when he wrote:

"If, by a miracle of mechanical ingenuity, a book could be so arranged so that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be accomplished by print."

Sidney L. Pressey realized Thorndike's "miracle" in 1926, when he exhibited the machine shown in Figure 1. This device presented multiple choice questions one at a time by rotating a cylindrical drum on which the questions were printed under a glass window. Students indicated their responses by depressing one of the four keys that corresponded to each choice in the question. In the test mode, no indication of the correctness of the student's response was supplied. In drill mode, all keys except the correct one were locked.

One exciting feature of Pressy's device was that it automatically recorded all responses. Pressey claimed that he used this information (an item analysis of sorts) to revise his lecture plans, spending more time on concepts that were consistently missed and less on those easily grasped. In a much later paper (1964), Pressey noted that an attachable mechanism existed for the 1926 device which would give the user a candy lozenge when a programmable number of correct responses had been made. This feature is especially interesting because it predates B. F. Skinner's writings in machine reinforcement by almost 30 years.

In 1927, Pressey refined the drill

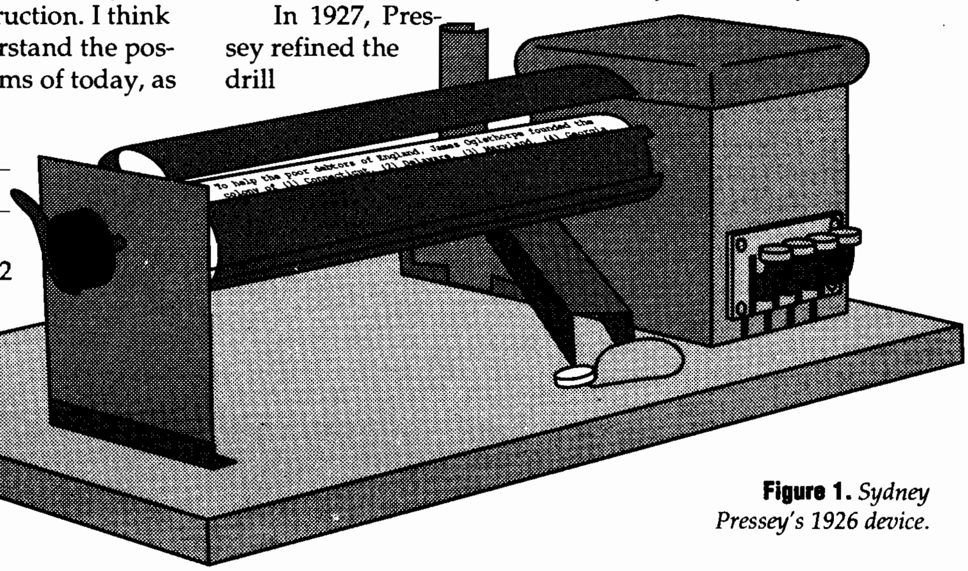

Figure 1. *Sydney Pressey's 1926 device.*

mode of his original machine to omit successive presentations of questions which had been correctly answered twice in succession (see Figure 2). Skinner adopted a similar contingency in 1958.

Pressey discontinued much of his research in 1932 due to a lack of funds — he sponsored most of his work out of his own pocket. He remained confident, however, that an "industrial revolution" was coming in education and publicized yet another two contributions to the technology of mechanized testing during that same year.

The first was a generalized answer unit consisting of a 3" by 5" card with numbered answer boxes that students would mark with their responses. By placing a transparent window over the students' cards, the teacher could easily distinguish correct responses from incorrect ones.

Pressey's second 1932 invention was more elaborate. The students' answer cards were pieces of cardboard with thirty rows of five circles each. Students marked their answers by punching through a circle. The card was then inserted into a machine consisting of 150 holes in the same configuration with spring-loaded pins in the correct answer positions. The device sensed the pins that protruded through the correctly punched holes, printed the number of correct responses on the answer sheet, and kept a running tabulation of the number of correct responses to each item — all at a rate of one answer sheet per second! The tabulated results could be read directly from the back of the machine to provide an instant item analysis to guide class discussion. If produced today, this device might seriously compete in the classroom market.

In 1934, James Little conducted one of the first studies to investigate Pressey's early testing devices. With Pressey's 1926 drill device and 1932 test scorer, Little found a significant difference between the final exam grades of students who were immediately informed of their results on preliminary exams and those of students who did not have this feedback.

Little also found that drill and the use of preliminary exams significantly improved final exam grades. It is interesting to note that Little found drill and immediate feedback to be of greatest benefit to students in the lower half of the scholastic distribution, while Reed, working in 1961, found programmed instruction to be most effective with students in the upper portion of the distribution (see discussion in Saettler, 1968). Little concluded that mechanical test scoring and drill devices have practical applications in the classroom due to their convenience, speed and possibilities for immediate reinforcement.

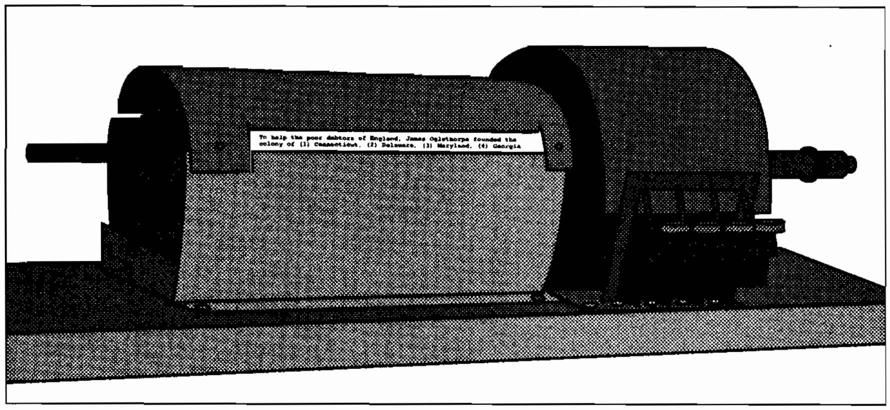

Figure 2. *Pressey's 1927 device omitted questions previously answered correctly.*

Even so, Pressey evidently felt himself to be somewhat of a prophet in the wilderness and inserted the following epilogue in his 1932 article: "The writer has found from bitter experience that one person alone can accomplish very

Remembering Sidney Pressey

Sidney Pressey, the late Professor Emeritus at The Ohio State University, is considered by educational leaders to be the father of technology in the classroom and is considered by many to be the inventor of drill and practice teaching machines. During his tenure at Ohio State, Pressey often humorously recounted his struggles to introduce technology into the classroom.

In one such story, Pressey discussed one of his early machines, which were very simple devices. One multiple choice tester consisted mostly of poking pins through an answer sheet so that the machine could read them faster. This quickly introduced a logistical problem— if students held the sheet on their leg, they would inevitably poke themselves. A revision was necessary — premade holes. Later a new problem emerged—the janitors complained of classroom floors scattered with little circles of paper. It wasn't until Pressey developed later machines that the confetti disappeared.

Students also remember a more serious side to Pressey's struggle. Although he was able to prove again and again that drill and practice exams dramatically increased performance and retention, he was never able to convince manufacturers that these machines could be a viable force in the education market.

Still, throughout a long career of frustration Pressey retained a high level of energy and enthusiasm and a warmth and concern for human beings. His vision: To integrate technology with solid, traditional teaching methods. The machines simply presented an important opportunity to reinforce learning for those who didn't do well in the traditional classroom. "Pressey was always more interested in people than machines," said one student, "and his interest in machines was derived from his recognition that technology could be used to serve those students he cared so much about."

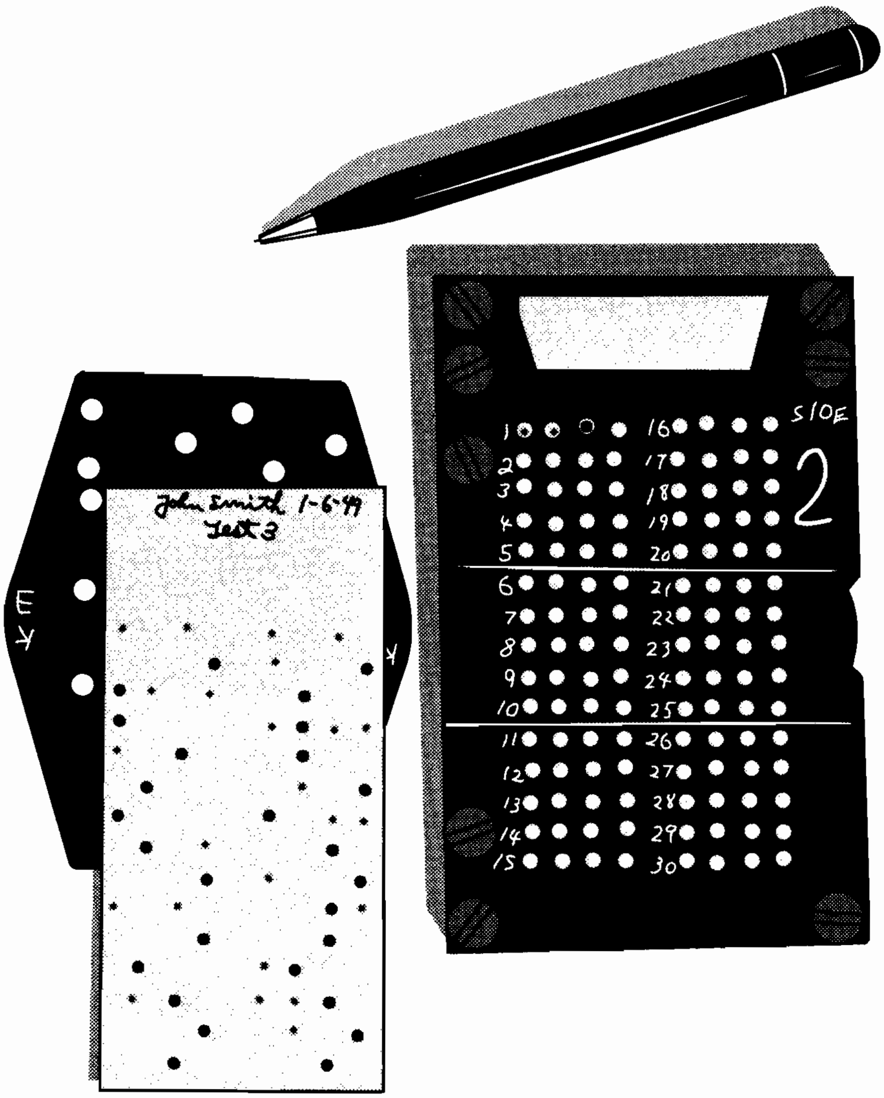

Figure 3. *Pressey's 1950 punchboard.*

little, and he is regretfully dropping further work on these problems. But he hopes that enough may have been done to stimulate other workers and that this fascinating field may be developed."

Eventually, however, Pressey's ideas would find adherents, and in the 1950's he emerged as one of the leading figures in learning theory as applied to teaching machines. He criticized Skinner's work severely on several counts and went on to oversee the development of computerized versions of his testing techniques while on the staff of the Educational Psychology Department at the University of Arizona.

Another significant piece of research on mechanized testing during the 1930s was conducted by John and Hans Peterson, who developed "chemosheets" that students could mark with a damp swab. Correct answers turned blue, while incorrect answers turned red. In 1931, John Peterson published the results of an investigation into the use of the "Self-Instructor and Tester," as the Petersons dubbed the process, in a class in introductory psychology. He used several control and experimental groups which all employed a multiple-choice test as a pretest, post-test, and study guide. The experimental group used chemosheets to accompany their study guides for reading assignments, while the control group used only untreated answer sheets. Peterson reported that the improvement of the experimental groups' posttest scores over their pretest scores was significantly greater that the corresponding improvement for the control groups, although it isn't known if chemosheets ever found much support elsewhere.

PUNCHBOARDS

When Pressey shelved his research in 1932, the development of mechanized testing and teaching devices went into a somewhat dormant stage for almost 15 years. It began to revive in the late 1940's, when George Angell and Maurice Troyer working together and Pressey separately conducted experiments with "punchboards." Angell and Troyer's punchboard (1948) consisted of an 8 1/2" by 11" sheet of paper covered with test items inserted between the front cover and middle section of a solid holder, both with five perforations for each item. An answer key was inserted between the middle section and the solid back cover. Students marked their answers by punching through the paper. The key was then visible through the hole, and red spots appeared for correct answers.

Pressey's punchboard, revealed in an extensive 1950 paper, was a 3" by 5" version similar to that of Angell and Troyer (see Figure 3). The difference was that students' pencils would not pierce the paper except through the correct response; mistakes would be marked by the pencil's lead. Pressey claimed that his punchboard "telescoped into one single simultaneous process the

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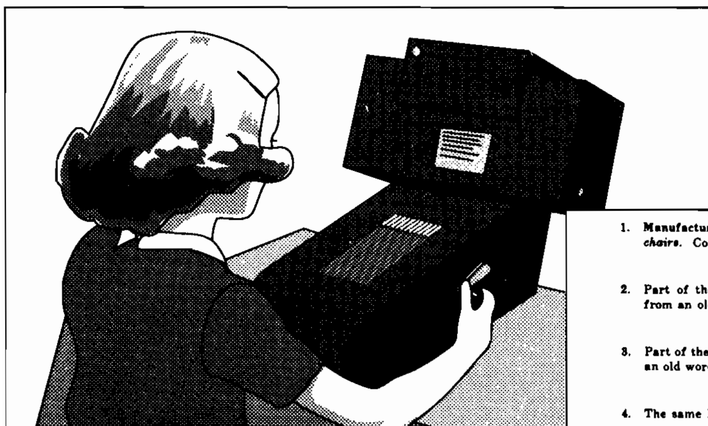
Use a Question icon with no attached anticipated answers instead of a Display icon, Wait, and Erase icon. It works exactly the same and uses only one icon.

taking of a test, the informing of the students as to their errors, and their guidance to finding the right answers."

THE AGE OF SKINNER

It would be impossible to discuss all the various learning devices that were developed throughout the first half of this century. Ibert Mellan reported in 1936 that over 600 inventions had already been patented as educational aids; the earliest on record was by H. Chard, who called his 1809 device a "Mode of Teaching to Read." While a great deal of ingenuity was exhibited in the design of these early testing and teaching machines, it appears they were used only nominally. Widespread acceptance of mechanized testing and teaching in public education would not occur until after World War II.

The beginning of contemporary educational technology



Figures 4. *1960 version of Skinner's first machine.*

is generally agreed to be B.F. Skinner's historic 1954 paper, "The Science of Learning and the Art of Teaching." It can be seen, however, that a great deal of work set the stage for the acceptance of Skinner's approach to education, including Sidney Pressey's, who was 30 years ahead of his time when he began experimenting in the 1920's.

B. F. Skinner criticized the state of public education in 1954 for emphasizing negative rather than positive reinforcement, and for lacking any regular reinforcement schedules designed to bring about changes in behavior. He attributed these shortcomings to prevailing class sizes and teaching methods as well as to archaic learning theories. As recently as 1968, Skinner argued that "what is taught often tends to be simply what can be measured by tests and examinations... [which] are designed to show principally what the student does not know." As reported by Robert Biehler in 1971, Skinner claimed that specific shortcomings of traditional teaching methods included:

Skinner's aim was to teach and question in such small steps that the learner would be led smoothly to complex behavior through carefully conditioned responses.

1. The lapse of time between an act and reinforcement.
2. Lack of a well-organized presentation of stages in teaching complex skills.
3. The relative infrequency of reinforcement

Skinner's solution to these problems was to introduce the principles of operant conditioning into the instructional process through the technique of programmed instruction. The two basic premises of this technique are "the gradual elaboration of extremely complex patterns of behavior and the maintenance of the behavior in strength at each stage." Biehler explains that Skinner's approach mandates "that the learning of students in school should be shaped by a series of reinforcements."

1. Manufacture means to make or build. *Chair factories manufacture chairs.* Copy the word here:

   □ □ □ □ □ □ □ □ □ □ □

2. Part of the word is like part of the word factory. Both parts come from an old word meaning *make* or *build*.

   m a n u □ □ □ □ u r e

3. Part of the word is like part of the word manual. Both parts come from an old word for *hand*. Many things used to be made by hand.

   □ □ □ □ f a c t u r e

4. The same letter goes in both spaces:

   m □ n u f □ c t u r e

5. The same letter goes in both spaces:

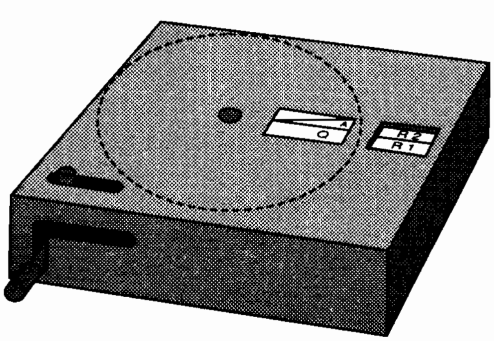
   m a n □ f a c t □ r é

6. Chair factories □ □ □ □ □ □ □ □ □ □ □ chairs.

Figures 5. *A typical set of frames for the machine.*

The machines that Skinner proposed supported his learning theory in two ways. First, they delivered reinforcement immediately rather than allowing delays of 24 hours or more to occur while teachers corrected students' work. Second, they progressed in a step-by-step manner to mold complex behavior.

Skinner's first machine, introduced in 1954, grew out of his desire to allow students to construct responses rather than simply select the correct statement in a multiple choice fashion (as in Pressey's and the Petersons' devices). This machine displayed questions on a tape, the bottom section of which was hidden from students and contained the answer coded by a series of punched holes. Students indicated their responses by positioning slides on the machine's front panel to appropriate letters or numbers. After the slides had been set, the student turned a crank. If the response was correct, the machine advanced to the next question. If incorrect, the crank would simply not turn. Thus knowledge of results and reinforcement (the positive



Figures 6. *Skinner's improved device.*

SENTENCE TO BE COMPLETEO	WORO TO BE SUPPLIED
1. The important parts of a flashlight are the battery and the bulb. When we "turn on" a flashlight, we close a switch which connects the battery with the ______.	bulb
2. When we turn on a flashlight, an electric current flows through the fine wire in the ______ and causes it to grow hot.	bulb
3. When the hot wire glows brightly, we say that it gives off or sends out heat and ______.	light
4. The fine wire in the bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of a(n) ______ current.	electric
5. When a weak battery produces little current, the fine wire, or ______, does not get very hot.	filament
6. A filament which is lass hot sends out or gives off ______ light.	less
7. "Emit" means "send out." The amount of light sent out, or "emitted," by a filament depends on how ______ the filament is.	hot
8. The higher the temperature of the filament the ______ the light emitted by it.	brighter, stronger

Figures 7. *Part of a sample program to teach high school physics.*

movement of the crank) were both immediate. One version of this machine (circa 1960) is pictured in Figure 4. A typical set of frames that might have been used with such a machine to teach a third or fourth grade student to spell the word "manufacture" is shown in Figure 5.

The shortcomings of this machine were quickly apparent. While the device seemed to function well for short answer responses, it could not allow complex responses to be formed. Skinner introduced another device in 1958 that addressed this problem (see Figure 6). This machine consisted of a large disk covered by a panel with two windows and a lever. A question was presented in one window, and students wrote their responses on a blank part of the disk exposed through an open slot in the other window. When they moved the lever, the correct answer was revealed in the question window, while the response just written was moved under a transparent shield so that it could be read but not changed.

An adaptable feature of Skinner's 1958 machine then came into play: The students themselves decided whether their responses were correct by comparing them to the printed answers. If they judged their responses correct, they moved the lever horizontally, causing a hole to be punched in the disk. This hole would cause the question to be skipped on subsequent revolutions of the disk. When the disk turned freely, students knew that they had answered all of the questions to their own satisfaction. This machine was very similar to Pressey's 1932 testing device, except that the responses were constructed rather than multiple choice and evaluated by the students rather than the machine.

Skinner concentrated very heavily on the construction of learning programs for his machines. His aim was to teach and question in such small steps that the learner would be led smoothly to complex behavior through carefully conditioned responses. Part of a sample program to teach high school physics students about the emission of light from an incandescent source is in Figure 7.

In spite of the improvements in Skinner's 1958 machine over his 1954 device and the care with which he tried to program his instruction, many problems still existed. For example, while students were rewarded for correct responses, they received no feedback or explanation when their responses were incorrect. This may have served satisfactorily with the minute steps of the 1954 machine, but the open-ended nature of the 1958 device led to problems in interpretation.

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To change the routing of an icon used as an answer, you may hold Command and click below the icon either on the map of icons or on the icon in the toolbox.

TUTORTEXT AND SCRAMBLE TEXT

Norman Crowder (1960) attempted to remedy this shortcoming with a technique he called "intrinsic programming." The basic premise of this approach was that students' responses should determine what material is presented next. The device Crowder used was simply a textbook in which material was presented a paragraph or so at a time. At the end of each discrete section, a multiple choice question was presented with a page number following each choice. Students turned to the pages that corresponded to their choices. If they were correct, new material was presented. If incorrect, review or reinforcement material was found. This scheme was used throughout the entire book, which Crowder termed a "TutorText." (It has also been called a "Scramble Text" elsewhere in the literature.) This technique has been used most recently by Robert Mager in some of his teacher training books. Sample pages from his book *Preparing Instructional Objectives* are in Figure 8.

The main advantage of intrinsic programming is that it does not waste the time of the fast learner with unnecessary repetition. Its disadvantage is that it requires a large textbook to present even a relatively small amount of material. Readers familiar with computer-based instruction materials . . . may recognize this strategy as a common approach to the programming of computer-based instruction courseware.

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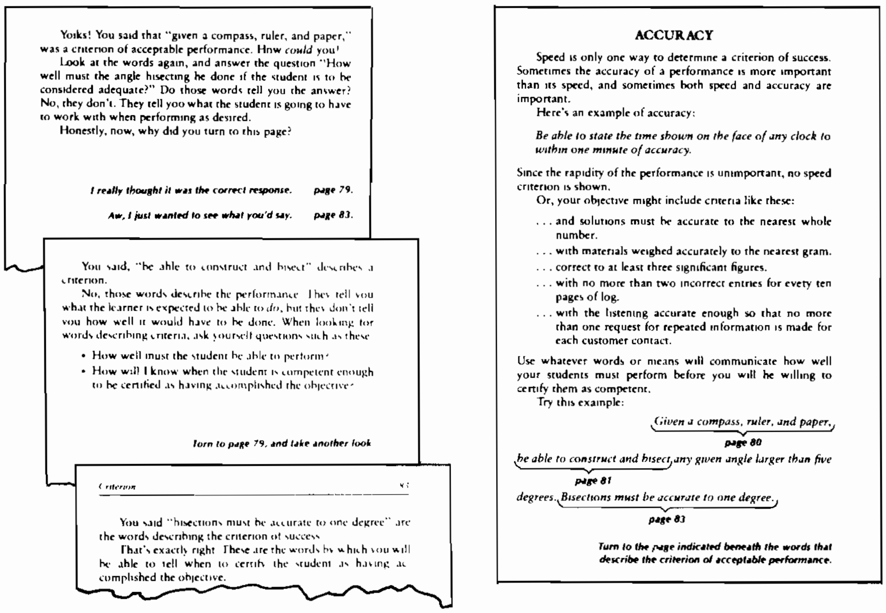

Yoiks! You said that "given a compass, ruler, and paper," was a criterion of acceptable performance. How *could* you!

Look at the words again, and answer the question "How well must the angle bisecting be done if the student is to be considered adequate?" Do those words tell you the answer? No, they don't. They tell yoo what the student is going to have to work with when performing as desired.

Honestly, now, why did you turn to this page?

I really thought it was the correct response. **page 79.**

Aw, I just wanted to see what you'd say. **page 83.**

You said, "be able to construct and bisect" describes a criterion.

No, those words describe the performance. They tell you what the learner is expected to be able to *do*, but they don't tell you how well it would have to be done. When looking for words describing criteria, ask yourself questions such as these:

- How well must the student be able to perform?
- How will I know when the student is competent enough to be certified as having accomplished the objective?

Turn to page 79, and take another look

Criterion 83

You said "bisections must be accurate to one degree" are the words describing the criterion of success.

That's exactly right. These are the words by which you will be able to tell when to certify the student as having accomplished the objective.

ACCURACY

Speed is only one way to determine a criterion of success. Sometimes the accuracy of a performance is more important than its speed, and sometimes both speed and accuracy are important.

Here's an example of accuracy:

Be able to state the time shown on the face of any clock to within one minute of accuracy.

Since the rapidity of the performance is unimportant, no speed criterion is shown.

Or, your objective might include criteria like these:

. . . and solutions must be accurate to the nearest whole number.

. . . with materials weighed accurately to the nearest gram.

. . . correct to at least three significant figures.

. . . with no more than two incorrect entries for evety ten pages of log.

. . . with the listening accurate enough so that no more than one request for repeated information is made for each customer contact.

Use whatever words or means will communicate how well your students must perform before you will be willing to certify them as competent.

Try this example:

Given a compass, ruler, and paper, **page 80** *be able to construct and bisect* **page 81** *any given angle larger than five degrees. Bisections must be accurate to one degree.* **page 83**

Turn to the page indicated beneath the words that describe the criterion of acceptable performance.

Figures8. *Sample page from Mager's book* Preparing Instructional Objectives.

sary repetition. Its disadvantage is that it requires a large textbook to present even a relatively small amount of material. Readers familiar with computer-based instruction materials written in standard CBI authoring languages may recognize this strategy as a common approach to the programming of computer-based instruction courseware.

Crowder developed a random access film reader to automate his TutorText by presenting pages of text stored on 35mm film (Figure 10). The device had an adding machine type keyboard with which students could indicate their responses. Using 35mm film, Crowder was able to present students with motion pictures as well as still frames.

Programmed instruction drew criticism from many of Skinner's contemporaries on a wide range of issues (see particularly Pressey, 1963, and Thelan, 1963). As a result of these and other factors, the use of programmed instruction and mechanized devices during the early 1960's was sporadic. Saettler (1968) contributed much of the controversy and misunderstanding surrounding these techniques to what he called the "machine-program dichotomy." He observed that people tended to separate machines and programs conceptually, and that many companies made wild advertising claims that were not documented by research. Looking at the history of innovation in education, Saettler noted that change in educational structure has always been slow and almost always occurs within the existing framework of the classroom. Since wide-scale use of programmed materials appeared to require a major change in the classroom framework, its adoption had been slow to this day.

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