Developing Programmed Learning Courses for Highway Construction Inspection Training

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This paper describes the characteristics of programmed learning and how they lend themselves to the area of construction inspection training. The purposes of this paper are (a) to demonstrate the efficiency of programmed learning, (b) to describe the limits of potential of this teaching process, and (c) to show the need for management, understanding, and involvement in all stages of development. More programmed learning efforts fail during their administration than in any other stage of their development. Some efforts fail for natural reasons: a poor program. For the most part, however, the majority of the efforts fail because management could not or did not see what programming really involved.

The Virginia Department of Highways has developed several programmed courses, the use of which has proven highly successful. As a result of the implementation of this training device, 90+ percent of all new construction inspector trainees receive training in mathematics, plan reading, specifications and standards, and fundamentals of leveling within 6 months of employment.

•BECAUSE of the highly competitive labor market, public service agencies are finding it necessary to employ an increasing number of young men and women with substandard academic preparation. There was a time in recent history when a distinct dichotomy could be made between education and training. No longer is such the case, however. Business and industry must now think in terms of both. It has become necessary to upgrade new employee education to the trainability level. Programmed instruction is proving to be a valuable instrument in bridging the gap between the educational standard required and the entering and terminal behaviors of the new employee. The purpose of this paper is to describe the rationale behind, and the effectiveness of, programmed instruction courses as they are being developed and utilized in the training and educational efforts of the construction division of the Virginia Department of Highways. Emphasis will be placed on the training of the new employee. Further, certain weaknesses of programmed instruction experienced, and remedial actions taken, will be discussed.

What is programmed instruction? Programmed instruction is a method of presenting knowledge that allows the learner, working alone, to grasp new material in considerably less time, retain it longer, and enjoy himself in the process.

Like most modern advances made possible by science, it is simply a practical application of principles that have been known and accepted for some time. Programmed instruction applies the discovery made by psychologists and educators that learning is most rapid, pleasant, and permanent when the learner proceeds by small, easy steps,

Paper sponsored by Department of Economics, Finance and Administration; Department of Urban Transportation Planning; and Department of Maintenance and presented at the 48th Annual Meeting.

tests his understanding as he goes along, and avoids making errors along the way. Programmed instruction applies this discovery simply and literally. It subdivides the subject matter into small bits of information, arranges these in a rational, cumulative sequence, and introduces frequent checks of the learner's progress.

There are certain specific characteristics of programmed instruction which lend themselves to inspector training. P.I., as it is often referred to, is goal oriented. That is, objectives are established before a program is written (10, p. 55). The objective of any program is to change behavior. In other words, it trains one who is performing erroneously to perform correctly, or it causes one to perform who previously did not have the capacity to do so. Obviously these are two distinct problems with two distinct approaches. Thus, the first step in the development of a program is to define the problem. This step is critical, for what might be considered a training problem very often is a supervisory one.

Assume the following problem as having been defined: the new trainees cannot relate their position on the project to the construction plans. The deficiency, in this situation, is that young trainees do not know the concept of project stationing. The objective of the program, then, is: Trainees will be able to locate field features on the construction plans.

Having determined the objective of the program, the next step is to determine a means of evaluation whereby it can be established that the objective of the program has been attained. This means of evaluation becomes a criterion.

There is an immediate, or an internal, criterion that is usually found in the form of a test at the end of the program. The other criterion, called an external criterion, determines the effect the student's attainment of a program objective will have on an organization's operations and is specified before the program is written. In this case, the external criterion might read: Less time will be lost because materials were delivered to the wrong station, or the young trainee reported an incident at the wrong location to his supervisor.

Although the preceding example is a gross oversimplification, it should be apparent that this approach cuts through all of the unnecessary "nice to know" information and arrives at the specific behavior that is required in the field.

The educational sociologists are quick to demonstrate how social class stratification is a definite factor in the non-achievement of the lower classes attending middle-class institutions. The same could be said about training efforts. Admitting that less than adequately prepared persons are being hired today, because of the labor market competition, is it not possible that training of sub-technical personnel is attempted using the professional values and judgments gained in the "ivied halls of learning?"

Programmed instruction, properly developed and implemented, negates this schism. It goes without saying that objectives will be derived on the basis of entering behaviors—the background knowledges, skills, attitudes and aptitudes—of the trainee population. It is this study of the target population that not only determines the objectives of a training program, but also the level of difficulty and the size of the information bits that will be offered. Thus, a pre-training screening device is mandatory in training program development. This pre-screening is automatically done in developing programmed instruction courses.

In 1965, the construction division of the Department conducted a training needs study. The results of this study, based on questioning practicing inspectors and engineers in the field, indicated that 33 combinations of knowledges, skills, and attitudes are required for the inspection and documentation of highway and bridge construction. The training needs were validated by testing a cross section of each level of responsibility (3, p. 39).

Despite the fact that the study provided a complete and comprehensive curriculum, so designed as to provide the trainee with a logical sequence of actions to compensate for inadequate background and to promote upward mobility in the power structure, there are practical problems involved in its implementation. One of the major problems is that of time. This is one of the cardinal reasons that the Highway Department investigated the potential of programmed instruction. The bulk of the new trainees

are employed, generally, at the close of high school in late May or early June. Because this is the busiest time of the construction season, all too often the young trainee is relegated to unproductive work because very few experienced supervisors could take the time (or, perhaps more accurately, attempt to take the time) to do any meaningful on-the-job training. Thus the new employee's potential goes unexplored until the winter schools. This assumes that he has not left out of sheer boredom. Because programmed instruction is a self-teaching methodology, this need not happen in the future. The new employee can begin immediately to learn about the task he thought he was being hired to do.

Despite the auto-instructional characteristic of programmed instruction, the Department's experience has demonstrated a need for interaction between the trainee and the trainer. The trainer, in this case, might well be his immediate supervisor on the job.

The curriculum specialists in education have long championed the idea that the student learns as a result of planned activities and guidance as well as from his formal course of studies. According to the Stanford Social Education Investigation: "The more completely a purpose is accepted and understood and a goal recognized, the more efficient the learning will be . . . ." (7, p. 58). With this in mind, the Department has recognized the need for orientation courses for trainers in what programmed instruction is and how it works. Subsequent to this orientation, programmed instruction is receiving greater acceptance and success.

One of the major principles of programmed instruction is that an active response is required on the part of the student (11, p. 259). A well-written programmed instruction course will have the student do exactly during the training what is expected of him in the field upon completion. For example: One skill necessary in the vertical control (or leveling) aspect of construction inspection is the ability to read the level rod (Fig. 1). What better way, then, to ascertain that the student could indeed read the rod than to ask him to read the rod exactly as he would see it under field conditions?

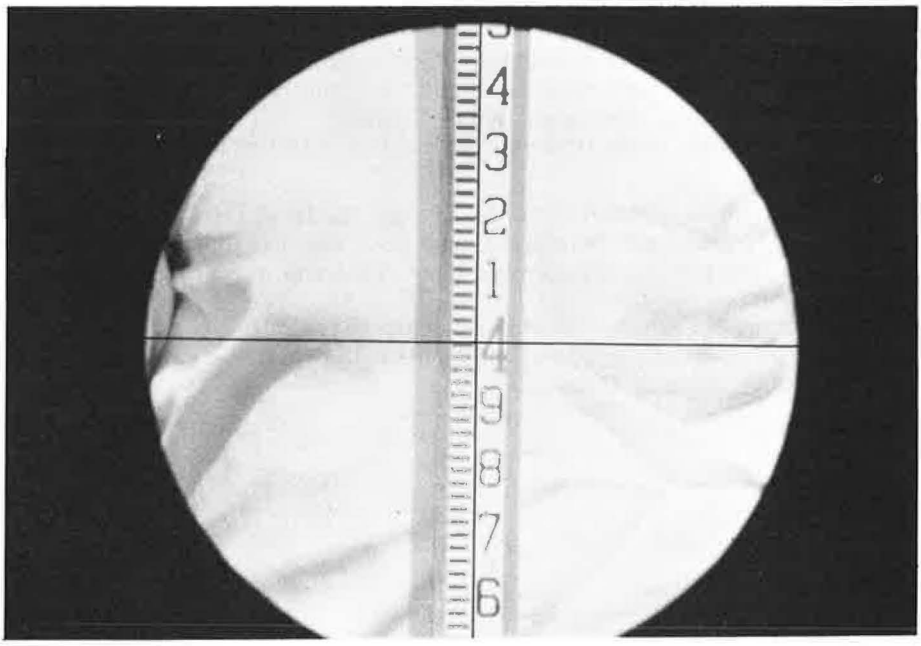

Figure 1.

Although the student can demonstrate an ability to read the rod by responding to a series of criterion photographs requiring correct readings, there still needs to be some planned activity of reading the rod under field conditions to develop proficiency. The criterion requirements are static, whereas the rod tends to waver under field conditions. In this respect, then, programmed instruction can act only in a complementary manner.

The self-pacing aspect of programmed instruction compensates for the variation of entering behaviors of the target population. This self-pacing is, perhaps, one of the greater assets of programmed instruction. The student does not have to concern himself with the progress of his peers, or for that matter, his own progress. It also encourages him to ask questions—for the question is already framed for him—he does not have to concern himself with trying to find the right words. Herein lies the opportunity for guidance by the trainer. Herein also lies one of the greater dangers of the use of programmed instruction. There is a tendency on the part of the trainer to "take over" the program. There must be a complete understanding of what programmed instruction is, and how it works, by those who are charged with the responsibility of implementing it. This can be accomplished by requiring the trainer to take the program that he is to monitor and also train him to write short programs of his own. The former action would give the monitor an understanding of the rationale behind the correct response required and the latter would train him to seek out areas of the student's difficulty and guide him through it without destroying the self-teaching characteristic of the program. As mentioned earlier, once the practice of orienting instructors in the nature and correct use of programmed instruction was initiated by the Department, success followed.

Analysis of the target population has already been noted as a prerequisite of good programmed instruction. Such an analysis will dictate the size of the knowledge bits—called steps—of the program. The principle of small steps in programmed instruction is misleading, for it brings to mind the question: How small is small? Suffice it to say that "small" indicates that amount of material necessary to progress with relative ease from one level of knowledge to the next level of complexity in the subject.

In summary, we submit a brief example of the process of programming to further an understanding of the mechanics of its development and also to show how this training tool lends itself to the area of construction inspector training.

To do this, certain basic assumptions will have to be made.

1. The target population has been studied and consists of high school graduates who have the capacity to do the fundamentals of addition, subtraction, division and multiplication of whole numbers, fractions, and decimals.
2. There is a need for these trainees to be able to use the instruments used in vertical control.

This small segment is restricted to how to read the level rod. The objective of this segment is that the trainee will be able to read the rod. The criterion will be satisfied when, in fact, the trainee will be able to read the rod with a high degree of accuracy and precision.

At this point, the programmer works backward to the initial point of no knowledge and designs a program of small bits of information to bridge the gap between no knowledge and proficiency (Figs. 2 through 7).

In the photograph below, there are two measuring devices. One is a level rod and the other a carpenter's rule.

Study the photograph carefully and answer the following questions.

1. The distance from the bottom of the carpenter's rule to the index finger of the right hand is _____ feet. There are _____ inches in this distance.

2. The distance between the "red" four and the "red" five on the level rod is _____ feet. There are _____ units between the 4 and the 5 which are/are not inches.

(underline correct answer)

Figure 2.

The answer to the preceding questions would be found elsewhere in the text as shown in Figure 2a.

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1. one foot twelve
2. one foot ten are not.

(You will note that the numbers on the carpenter's rule that represent inches do not correspond to the numbers on the level rod. Therefore, since there are only ten units between the foot marks on the level rod, each of the black numbers must represent a tenth (0.1) of a foot.)

1. In the photograph below, the pencil is

one-third
one-fourth CHECK THE CORRECT ANSWER
one-half

of the distance from the four to the five. Therefore, the pencil indicates a measurement of

four feet five inches
or CHECK THE CORRECT ANSWER
4.5 feet

Figure 2a.

Figure 3.

Answers

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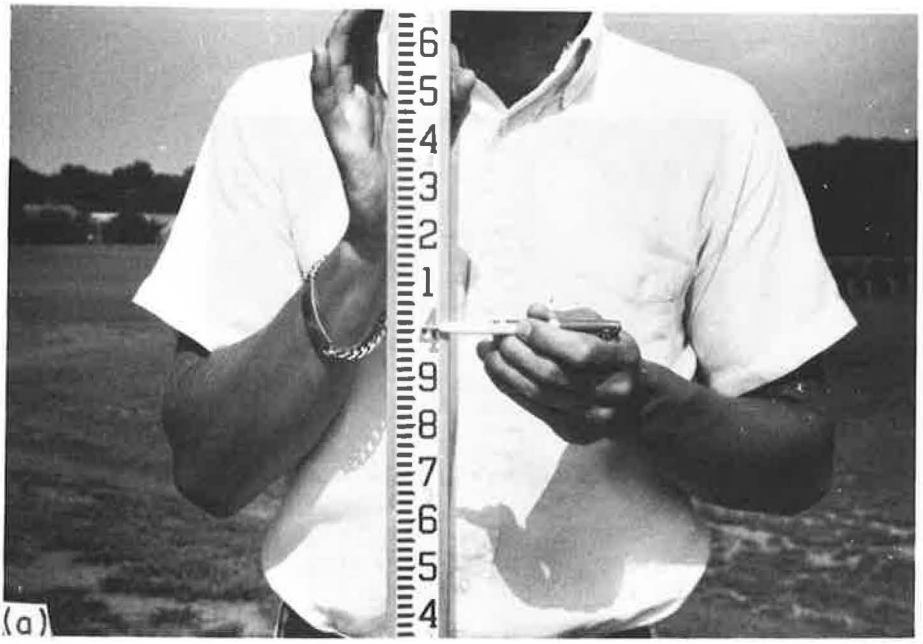
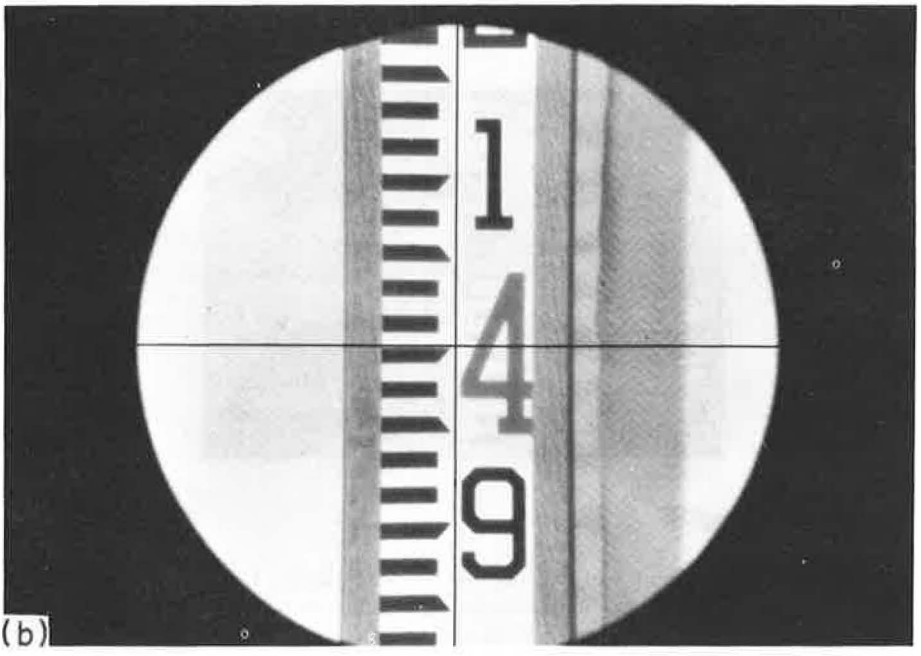
1. one-half 4.5 feet (REMEMBER THAT THE LEVEL ROD IS DIVIDED INTO TEN UNITS BETWEEN EACH FOOT AND EACH OF THE UNITS THEN REPRESENTS A TENTH OF A FOOT.)

Figure 3a.



"Red" numbers denote even feet and black numbers denote tenths of feet, NOT INCHES, but tenths of feet.



View of above rod reading as seen through the level.

Figure 4.

Study the photograph below. The cross hairs indicate that the reading is between _____ feet and _____ feet.

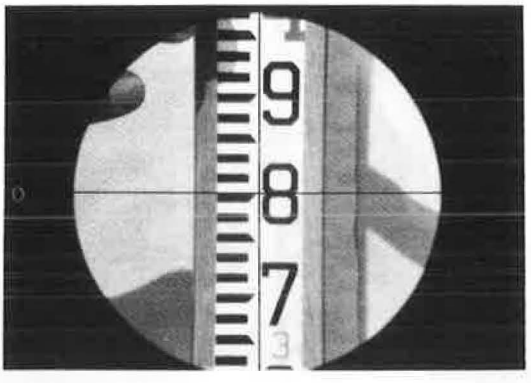


figure f

HINT: AT THE TOP OF THE PICTURE IS ENOUGH OF A CLUE AS TO WHAT THE NEXT FOOT WILL BE. ALSO, SOME LEVEL RODS HAVE LITTLE "RED" NUMBERS AT REGULAR INTERVALS FOR YOUR CONVENIENCE.

You are right, the cross hairs indicate a rod reading between 3 feet and 4 feet. The cross hairs further indicate that the reading will be _____ tenths of the way from 3 feet to 4 feet. The reading then should be written _____ feet.

Figure 5.

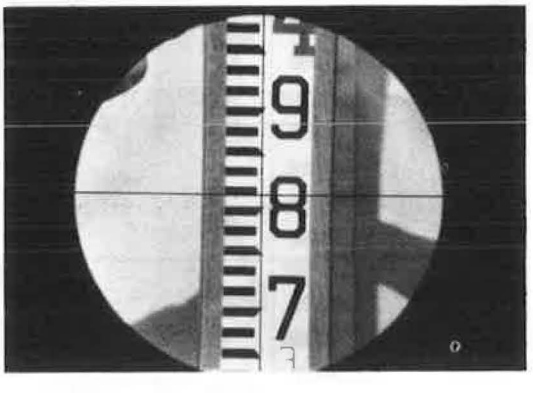


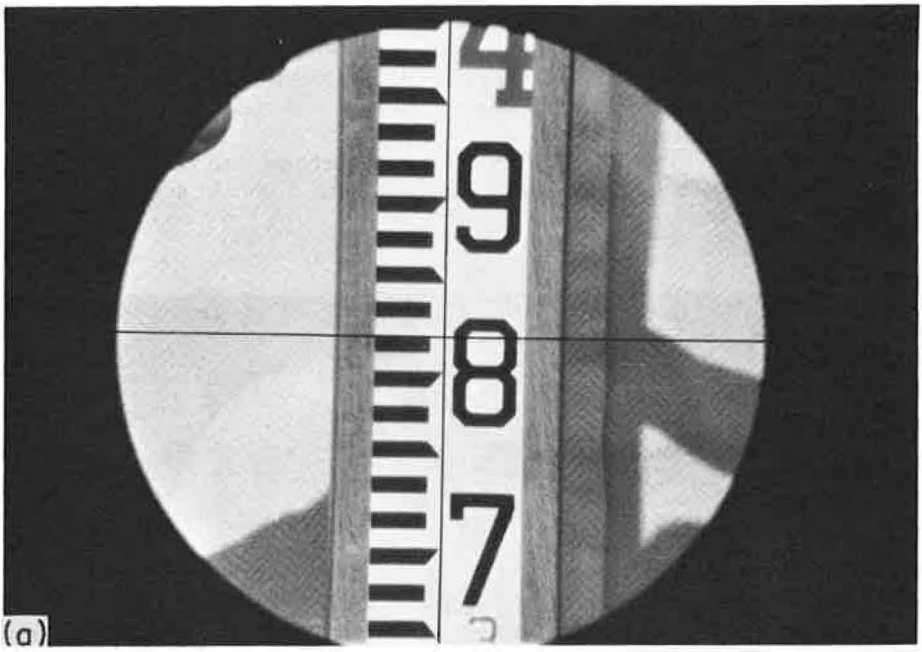
figure g

Remember that we said that the black marks were exactly 1/100 of a foot thick. Look very closely at the position of the horizontal line in figure f and the position of the horizontal line in figure g. If the black marks are 1/100 of a foot thick, then so are the white spaces. Thus this reading in figure g would be read 3 feet plus 8 tenths of a foot plus 1/100 of a foot or 3.81 feet.

Figure 6.

Give the rod readings for figures below:

(a) _____
(b) _____



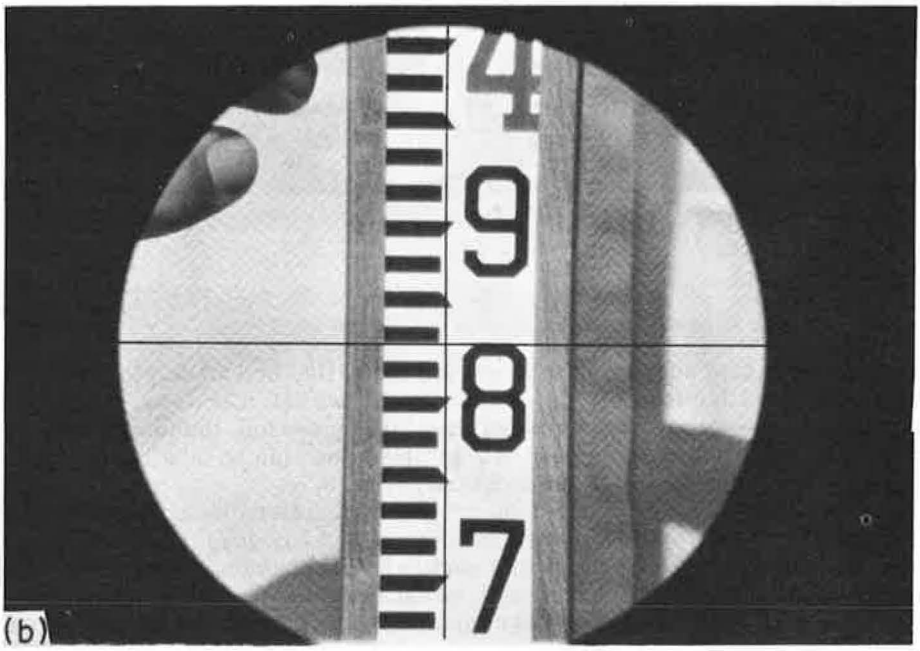


Figure 7.

The original program would take students stepwise (1/100 of a foot at the time to the next even tenth of a foot). Therefore, it is conceivable that the program would include many more photographs.

It should be noted that the programmer has constantly checked to assure that the steps are not too large for understanding by testing the material on one or two persons representative of the target population.

It was noted at the beginning of this summary that this example is but a very small segment of a much larger training effort called Leveling for Construction Inspectors. Before the final training program is published, it is field tested on a much larger segment of the target population. Where there is difficulty—noted by incorrect responses-revision takes place until greater than 90 percent of the target population makes the correct response.

The question might arise as to how programmed learning can be applied to the required actions such as plumbing the rod. Figures 8 and 9 should answer this.

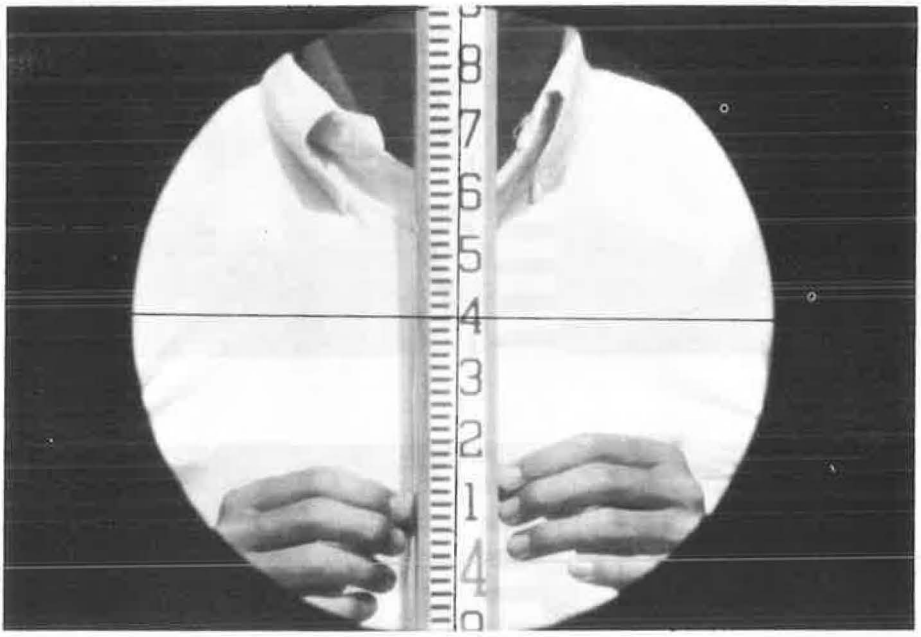


Figure 8.

By giving the trainee something to associate mentally, he can relate the required action, and thus practice on his own. For instance, we tell a trainee, using photographs, that if he were to hold the rod between his fingers and thumbs in such a way that it barely touched any of them (Fig. 8), he should be able to take his hands away, and the rod should stand by itself, momentarily (Fig. 9).

The length limitations of this paper do not permit a fuller discussion of the potential of programmed instruction in the training of highway construction inspector trainees. Maximum effectiveness of this particular methodology is experienced when upper and middle management realize what programmed instruction is, and what it can and cannot do. All too often programmed instruction is viewed as a panacea when such is not the case. Programmed instruction will not make any lasting effect on the training efforts of business and industry because it has been accepted in view of what

Figure 9a.

Figure 9b.

it will do instead of what it can do (8, p. 1). Programmed instruction can provide for a logical sequence of actions that provide for study, activity, and guidance because of the nature of its construction and development. Programmed instruction can save vast amounts of time and costs because it does get to the specific behavior, or task, that it required.

In an address (9, p. 7) to the annual meeting of AASHO, Robert Schmidt asserted:

> . . . an inspector, when working on a particular item, needs knowledge of just that particular item. An engineer, of course, needs to understand the entire background of the problem, but the inspector needs only to deal with specific problems on a specific day. Because of his educational background, his knowledge also needs to be refreshed each time he progresses to a new type of work.

Realization that specialization has become necessary because of ever-increasing technological knowledge is being accepted with the slowness of geological time. When the time comes that it is fully appreciated, there is a valuable instrument, because of its very nature, available for training these specialists, namely, programmed instruction.

REFERENCES

1. Brethower, Dale M. Learning Theory. Univ. of Michigan Press, Ann Arbor, 1965.
2. Havighurst, Robert J., and Neugarten, Bernice L. Society and Education. Allyn and Bacon, Inc., Boston, Mass., 1967.
3. Roy Jorgensen and Associates. Construction Division Training Needs Study. Virginia Department of Highways, Richmond, 1965.
4. Lysaught, Jerome P., and Williams, Clarence M. A Guide to Programmed Instruction. John Wiley and Sons, Inc., New York, 1963.
5. Mager, Robert F. Deriving Objectives for the High School Curriculum. N.S.P.I. Jour., Vol. 7, p. 7-14, March, 1968.
6. Mager, Robert F. Preparing Instructional Objectives. Fearon Publishers, Inc., Palo Alto, California, 1962.
7. Oliver, Albert I. Curriculum Improvement. Dodd, Mead and Company, New York, 1965, p. 58, citing Bush, Robert N., The Teacher-Pupil Relationship. Prentice Hall, Inc., Englewood Cliffs, N. J., p. 129, 1954.
8. Rummler, Geary A. Programmed Learning: The Whole Picture. Reprint from Training Director's Jour., April 1963.
9. Schmidt, Robert D. Illinois Program for Specific Task Training. Talk given to 52nd annual meeting of AASHO Committee on Construction, Wichita, Kan., 1966.
10. Scharder, Albert W. The Process. In Managing the Instructional Programming Effort, ed. by Geary A. Rummler, Joseph P. Yaney, and Albert W. Schrader, Univ. of Michigan, Ann Arbor, 1967.
11. Wahl, Richard A. A Report . . . In Managing the Instructional Programming Effort, ed. by Geary A. Rummler, Joseph P. Yaney, and Albert W. Schrader, Univ. of Michigan, Ann Arbor, 1967.