Let's Take The Mystery Out of PI!

Does PI Really Have a Solid Basis in Learning Psychology?

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Since its introduction as a training tool, programmed instruction has been frequently described as an educational revolution originating in the learning psychologist's laboratory. One psychologist has written: "Programmed instruction is the first application of laboratory techniques utilized in the study of the learning process to the practical problems of education." Claims by manufacturers of teaching machines and purveyors of programmed materials, of course, have been far less conservative. To the general public and the professional educator alike, it has seemed that at last the concerns of teaching have indeed become the concerns of science.

But in spite of the scientific aura surrounding the new "technology," there are at least two basic incongruities, disturbing to the professional educator who has taken the trouble to assess the theories and uses of P.I. First, there is the unsettled question of who is really qualified to create programmed materials. A learning psychologist, or at least an educational psychologist, would seem to be the logical first choice. And while the initial practice was to employ a psychologist as a programmer, most professionals are now recruited from within company ranks and have little, if any, background in learning psychology.

The authors of a recent report on the selection and training of programmers have concluded that the ideal programmer should have a high

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linguistic ability, high mental ability, a wide interest level, an ability to withstand confinement, and a few other personal characteristics. But nowhere in the study is it reported that it is necessary to know and be able to apply the principles of learning. In fact, the summary of the report specifically recommends that any discussion of learning theory be delayed until the student has had experience in frame writing. Clearly there is a discrepancy between who *should* write programs and who *can* and *does* successfully write them.

Lack of New Technical Information

A second inconsistency is evident in the subject matter of current articles appearing in professional programming publications. There is an abundance of the type article that expresses the opinion that PI is here to stay or that "programmer" should be spelled with two "m's". But the technical articles discussing the learning psychology foundations and research on programming, so prevalent several years ago, can no longer be found. The serious programmer is forced to conclude that either all that is to be said has already been printed, or that the scientific foundations of programmed learning were more apparent than real.

Faced by a formidable array of gadgetry and technical terms, the task of determining how and where and when PI fits into the total training effort is not an easy one. In order to evaluate an individual program, employ and supervise programmers or even work with an outside programming firm, it is imperative that the training director or training person responsible for the development and implementation of programming efforts understand the learning principles underlying programmed instruction and be able to ascertain the extent to which these principles are crucial to the "art." Without this knowledge, programmed instruction and teaching machines can offer costly pitfalls to the unwary.

PI and Laws of Learning

Because of the great majority of programs studied and in popular use are of the Skinner or linear variety, the following discussion will be restricted to those learning fundamentals thought to be the bulwark of the linear program. There are six important generalizations fundamental to the teaching machine and programmed instruction: operant conditioning, reinforcement, immediacy of reinforcement, discriminated stimuli, extinction and shaping. An analysis of these six fundamentals and how they correlate with recent research will help us pinpoint the exact relationship between the laws of learning and programmed instruction.

Operant behavior, according to Skinner, is that behavior emitted by the organism, but not elicited by the environment. In other words, there is no particular, observable stimulus which will consistently elicit an operant response. The learning of operant behavior, called operant conditioning, consists of strengthening an operant by making a particular response more probable or more frequent. This is achieved by reinforcing the operant response when it occurs. The strength of operant conditioning is measured by its rate of emission. Raising or lowering this rate of emission, according to Skinner, constitutes learning.

By manipulating operant conditioning, pigeons can be trained to peck at different colored lights and rats trained to bar press or any of a multitude of behavior patterns. Applied to human learning by programmed instruction, operant conditioning takes the form of questions and answers. The question (or statement to be completed) provides the stimulus to which the learner responds by constructing an answer. According to Skinner and his followers, the activity of answering questions is the same as the activity of emitting responses. By reinforcing correct answers/responses, a particular operant can be strengthened.

Overt vs. Covert Response

In all cases, however, the response must be overt, i.e., it must be written out. A covert response would violate the principle of operant conditioning. For this reason, directions to early programs emphasized the need for the student to write his response in each frame. It was, however, not long before students found that thinking the response worked about as well as writing it.

The great majority of later studies undertaken to demonstrate the importance of the overt response have found no significant difference between the amount of learning produced by overt or covert responding. Taking into account both time and amount of learning, some studies have even demonstrated that the covert response is more efficient.

The translation of the principle of operant conditioning into student constructed responses appears inaccurate. When steps are made very small and the possibility of error held to a minimum, overt responding is probably unnecessary. Anecdotal records of student reactions to programs support this contention. A more important response requirement is probably related to the kind of response the frame requests. In an experiment by James Holland, it was demonstrated that students made the fewest errors on a post-test when the responses required were related to the critical information in the item. This suggests that mere activity is not sufficient, but that the stimulus question must force some kind of internal response which demands a high level of interaction between the student and the material.

Reinforcement

A second important generalization fundamental to programmed instruction is the principle of reinforcement. The term reinforcement refers to any of a wide range of conditions which may be brought into a given learning situation to increase the probability that a given response will reoccur in the same situation. The list of conditions that may be introduced is long and diversified and includes such reinforcers as food, water, electric shock avoidance, money, grades, and trinkets. And although it is clear that the empirical operation of reinforcement is essential to learning, the exact nature of the mechanism of reinforcement is not. Reinforcement under one set of conditions may not be reinforcement under another.

By using the technique of reinforcing certain actions in the presence of certain stimuli and not reinforcing other actions, very complex behavior repertories can be built up in animals. Skinner's ping-pong playing pigeons are a good example of the application of reinforcement techniques used to develop a complex behavior repertorie.

When translated into human learning and programmed instruction, reinforcement is defined as response confirmation or telling the student that his response was correct. The student's "knowing" that he was correct is interpreted as providing that reinforcement which will increase the probability of the reoccurrence of a given operant.

Successful students report, however, that because step size is small and the error rate is low, it is a simple task to determine the answer in any given frame. Because it is easy, many students do not bother to check their answers. Whatever reinforcement properties the answers may have possessed is lost for these students. Yet they do as well as their reinforced counterparts. Knowledge of results is at best a questionable reinforcer.

Immediacy of Reinforcement

The third fundamental, immediacy of reinforcement, sets forth the time relationship of reinforcement to response. Increasing the delay of reinforcement after a response has occurred introduces an increasingly long chain of responses between the desired response and reinforcement which may interfere with learning. Wolfe, in a representative experiment found that a delay of reward for as short as five seconds reduced the learning of a single T-maze by rats. Longer delays produced progressive decreases in efficiency, with the greater part of the decrease occurring within the first minute. The majority of studies with programmed instruction support the principle of immediacy of reinforcement as contributing to learning. Scattered studies report comparable learning from students informed about their performance as much as twenty-four hours later.

A second aspect of the time relationship between response and reinforcement is concerned with the pattern according to which reinforcers follow responses. If reinforcement is given after every correct response, the schedule of reinforcement is said to be continuous. The majority of programs operate on a continuous schedule. Any other schedule of reinforcement, given on a time-contingent basis or for a certain proportion of correct responses is referred to as an intermittent schedule or partial reinforcement. Each type of schedule affects responding in characteristic ways. In general, more responses per reinforcer are obtained on an intermittent schedule than on a continuous schedule. If reinforcement is withdrawn, responses continue and resistance to extinction is greater after training with intermittent rather than continuous reinforcement. Human learning through programmed instruction has not revealed any correspondence between post-test results and a particular schedule of reinforcement. This fact should not be surprising, however, if knowledge of results is a highly questionable reinforcer to begin with. No particular schedule of presentation can be expected to affect learning. Immediacy of confirmation also comes into question by this logic, for if the student already knows the answer before he receives reinforcement from the program, no delay of reinforcement can be said to exist.

Operant Discrimination

The fourth principle of programmed instruction is concerned with operant discrimination. In an experiment where a pigeon is trained to stretch his neck when a light comes on, the light is said to have become the stimulus occasion upon which the neck-stretching response is more likely to occur. The process through which this behavior is produced is called discrimination. In a program the discriminated stimuli are the questions that require appropriate answers. The use of operant discrimination is not, of course, the exclusive device of programmed instruction. The mechanical agency of the frame serves the purpose of isolating the discriminative stimuli so that they may be more easily recognized, but beyond that discriminative stimuli in programs deserve no special attention.

Extinction

A fifth principle is the principle of extinction. If a response has been developed to a high rate through reinforcement techniques, it can be extinguished or reduced to its original rate of emission by failure to continue reinforcement. In programmed instruction, the operation of extinction is implicit in the method. If a response is unreinforced, it will be extinguished. If response confirmation does not take place, the response will return to operant level. Extinction operates, however, in any educative situation when a given response goes unreinforced. Again, programmed instruction can lay no special claim to its use.

Shaping

The sixth principle is referred to as shaping. Shaping behavior is the process of producing a learned complex sequence of responses. This is accomplished by reinforcing each unit of the sequence until the entire chain has been established. The laboratory concept of shaping has been translated into programmed instruction by reducing information to very short steps and placing these steps in an ordered sequence leading to a specified terminal behavior. Each bit of information is presented separately and reinforced separately at first. Gradually, the learner is led down a special path to a complex goal behavior. Step size is kept small to ensure a high probability of reinforcement.

In theory, shaping in a program appears to function in the same general way as shaping in the laboratory. In practice, however, complications arise in defining the meaning of step size and in determining what a logical sequence is. No one has been able to do either so that clear procedures can be laid out for programmers. Size of step has been measured in a number of ways, none of which offers concrete guide lines. In general, programs with small steps, measured in any of the devised ways, have produced more efficient learning.

The exact nature of a logical sequence also eludes definition. Three of five experiments reported by Wilbur Schramm show no significant difference in learning when program items were placed in random order or what the programmer considered a logical sequence.

Task Analysis

In a paper presented by Robert M. Gagne at the 69th Annual Convention of the American Psychological Association, an attempt was made to focus on those principles of learning which could be applied to the practical problems of military training. After examining the well-known principles of reinforcement, distribution of practice, meaningfulness, distinctiveness of the elements of a task and response availability, Gagne arrived at the conclusion that there was not much to be drawn from these principles in the way of practical advice. Instead he turned to the techniques of task analysis as providing the greatest usefulness in designing effective training procedures.

Gagne's conclusion is similar to the one to be drawn from the relationship of learning principles to programmed instruction. In the final analysis, the most important outcome of the entire PI movement is the systematized attempt to prepare objectives and then teach in terms of them.

Summary

Although a learning psychologist was responsible for the teaching machine/programmed instruction movement, learning psychology has not really provided the solid foundations of established learning principles some would like to believe it does.

It would be, however, just as incorrect to conclude that programmed instruction has little or nothing to offer present training methods. Programmed instruction has operated on American education and training as a positive force, focusing our attention once again on the learning process and the methods we use to aid this process. PI's success as a method of communication, however, only incidentally rests on learning theory.

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