The Computer as Teaching Aid

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In spite of the fact that psychologists have been investigating learning for many years, we still have no completely satisfactory theory of learning that will permit us to exert precise control over all the variables that exist in a learning situation. In fact, some people would argue that we have not even identified all the variables. We have no good idea of what is involved in concept formation, and we do not know how to guarantee that learning will generalize from the training situation to the job situation. In spite of these gaps in our theories, however, some principles of teaching have evolved over the centuries. It is of interest to note that when a number of great teachers analysed their methods and wrote down rules for successful teaching they all emphasized, more or less, the same points:

Information should be presented in a logical step-by-step sequence.

Learning should proceed from the known to the unknown.

Instruction should proceed at a student's own pace.

Efforts should be made to ensure the student's understanding of each point before he proceeds to the next.

Misunderstandings should be detected and corrected immediately.

New ideas should be made meaningful in terms of the student's own experience.

The student should actively practice what he is learning.

Instruction should be fitted to the comprehension of the learner.[1]

Much of the excitement about the method of programmed learning stems from the fact that it provides some new ways for implementing these teaching principles. Programmed learning offers a practical means for the *individual* participation of the learner, a condition that is rarely possible in current group instructional practices. In addition, the careful way in which programmed instruction must be prepared calls for the explicit statement of the goals of the learning sequence, an analysis of the concepts that have to be taught, and a determination of a logical sequence in which the ideas can be presented. Programmed learning, therefore, seems to provide a means for putting the teaching principles into practice. However, the way in which most programmed learning sequences are being written has caused many educators concern. The basic problem is to define the goals of a learning sequence. Most programmes 'at present make use, almost exclusively, of verbal symbols. What the student learns to do is to manipulate words: is this the goal of learning? If the student learns to make certain verbalizations in response to verbal clues, will the learning generalize to situations in which stimuli may involve physical objects and social relationships as well as words? It has not been demonstrated conclusively that a variety of ways of presenting information is essential for efficient learning and generalization. However, the efforts of educators in this direction suggest that they feel it is a very important variable.

Educators are also aware that motivation is a crucial problem. A student who is motivated to learn a subject can often manage to learn it despite poor learning conditions. The problem is to motivate the student to want to learn in the first place, and, once he has started, to motivate him to continue studying. "Good" teachers have the ability to stimulate the natural curiosity of students. Reinforcement theories have told us the conditions and latency of reinforcement that will keep an organism behaving at a high rate. However, as yet, we do not appear to have devised ways of incorporating the motivational aids into auto-tutoring.

Another problem is that of measurement. In spite of many efforts, we still have no reliable measuring instruments with which to evaluate the results of our educational efforts. Standardized tests have been developed, and they represent a partial answer.

What does this analysis of the status quo mean for automated tutoring? It certainly suggests that instrumentation is desirable — if we want to do more than teach students to manipulate written words and if we want to investigate a variety of ways of presenting information. It suggests that we need instrumentation broad and flexible enough to enable us to pose some questions, collect the data, and determine which characteristics are important and which are not. It suggests that such instrumentation should provide for the controlled presentation of information in the appropriate sense modality, for controlling the conditions of reinforcement, for measuring the effects of what we are doing, and for responsiveness to the learning needs of the individual student. It suggests that simple mechanical teaching machines or programmed textbooks will not enable us to ask the necessary questions nor collect the data we need. It suggests the need for a device with broader capabilities.

Constructed-Response Devices

Most of the early development and experimentation connected with constructed-response programmes resulted from the work and influence of B. F. Skinner at Harvard University[2]. Skinner apparently began using teaching machines as a technique for applying his principles of learning, and, after extensive experimentation, found that the exercise of control over behavior was best achieved by careful and selective rewarding, or "reinforcement," as he prefers to call it. According to Skinner, the traditional classroom situation does not provide reinforcement, or reward, often enough or strongly enough to meet the criteria of effective learning. The teaching machine offered a possible solution to the problem by giving immediate reward after each step in the completion of a programme of learning. His view of an adequate teaching machine embodies this principle by allowing him to learn the validity of his answer as soon as he has given it. Another principle espoused by Skinner and his followers is that recall or reconstruction of data, to use his term "emission of a response," is more effective in learning than simple recognition; hence, they prefer the use of a constructed-response rather than a multiple choice programme.

Basically, Skinner thinks of the machine and programme as a "teacher." That is, the programme is a teacher and the machine is only a device to bring the student into direct contact with that teacher.

A machine is thus a kind of private tutor. Machine design, on these grounds, must provide for:

1. Direct interchange between student and programmer which will induce sustained activity (response and feedback);
2. Ascertaining that each step is clearly understood before the student moves on to the next step;
3. Control of the sequence, so that students are exposed to new material only when they have been thoroughly prepared and success is very likely;
4. A sufficient indication of the correct answer (called clues, cues, hints etc.) to maintain a low error rate;
5. A method of immediate reinforcement that will maintain and strengthen the desired behavior pattern. (correct response)[3].

In 1956, Skinner was already contemplating a teaching machine that would combine the capacity of an electronic computer with the facility of a typewritten response. The computer would store the programme and feed it to the student in a predetermined sequence; the student would respond by using the typewriter connected to the computer. The computer could then score the response, inform the student, record the attempt, and proceed to the next question.

In 1958, the International Business Machine Corporation assembled a machine which combined the I.B.M. 650 Digital computer and an electric typewriter input, and programmed the computing machine to teach binary arithmetic. The machine had two interesting and unique characteristics:

1. It indicated the wrong answer (provided knowledge of results) after each digit was selected. This was expected to reduce the total number of errors during training as compared with the errors produced when the student attempts to select the entire sequence of digits before learning of his success.

2. It selected new problems according to the number of previous errors by the student. A student whose work was relatively free of error might be allowed to skip some of the practice steps, for example.[4]

The machine functioned rapidly; each problem could be checked in fifty milliseconds, and as many as ten input stations could be used simultaneously with one computer. However, the complete system was very expensive, and it may be that such an elaborate teaching machine can be justified only in a few rare cases, except for experimental purposes.

Essential Requirements of a Teaching Machine

The following requirements appear to be essential[5]:

1. *Display* — the presentation requirement is fulfilled by the display unit. Through the use of appropriate communication channels, the subject matter is presented to the learner in accordance with the nature of the material to be taught. Typically, some critical information is followed by a question or a cue to which a response is to be made.
2. *Response* — this requires a unit which implements the response initiated by the learner. The form of the learner's response depends upon the education and/or training purpose involved. It determines the characteristics of the machine's response unit.
3. *Pacer* — this is a requirement implemented by the pacing unit, a timing device which can alter two critical time intervals: (a) between the presentation of the cue or question and the presentation of the correct information or answer; and (b) between one cue or question and another. Pacing may also relate to the rate at which information is presented.

4. *Comparator* — the comparator requirement is provided by a comparator unit which either automatically analyzes the learner's response by comparing it with the appropriate correct response stored in the machine, or it allows the learner to make this comparison himself.

5. *Knowledge of results or feedback* — is a requirement for communicating to the learner the correctness or incorrectness of his response. The most simple and common type of feedback occurs when the learner is allowed to compare his response with the criterion or correct response; in that case it may be a byproduct of the comparator. However, the feedback process may be implemented by the machine — a particularly desirable feature if the learner is a young child or low in ability.

6. *Collator-recorder* — is the requirement to measure and record the learning process. It is usually implemented by either a collator or a simple recorder unit. Both collect such data as the number of errors, the type of error, and the time intervals required for response. The recorder may simply accumulate these data; however, a collator records them in such a way that each item is collated with the part of the programme to which it pertains. The data can then be made available to the teacher, the learner, the machine, or any combination of them. Typically, the data will be used *post facto* by the teacher-programmer to diagnose the learner's special difficulties. It is also useful in making improvements in the instructional programme.

7. *Selector* — this requirement exists whenever there are alternatives in the programme presented to the learner; the selector unit selects the next item in the programme. It can vary in operational complexity. The simplest form is binary; there are at least two possibilities for the next display, depending upon whether the response is right or wrong. Following a wrong response, there is either no change in the display or else a previous item in the programme is selected.

8. *Library* — this requirement, for the storage of information to be used as needful by the learner, is implemented by a library unit. Salient features of the library are its capacity, access time, and form, or medium of storage. Capacity may vary from approximately five items (Stoluvow and Porter's device), to a very large capacity numbering in the thousands as in the Crowder Autotutor and the I.B.M. 650 Computer.

9. *Programming* — is the requirement for a sequence of items; however, the particular ways in which items are sequenced can be quite different. A sequence can be entirely predetermined — a linear or non-interpretive programme — or it can be determined as the learner makes his responses —

a branching or interpretive programme. Regardless of type, the programme is a subject matter organized according to some plan and/or sequenced according to a set of programming rules.

10. *Computer* — the computer is a prime requirement for a versatile teaching machine system. It can perform all the functions described and has now been incorporated in the more sophisticated teaching machines such as Pask's, the I.B.M. 650, and the University of Illinois' Illiac teaching machine. The computer requirement is typically implemented by less costly components; however, a high-speed electronic digital computer may turn out to be more efficient for doing the job. The computer's function is to compose variant programmes from a basic programme as needed by each learner in the course of the teaching session itself. It has its own programme telling it what to do in case of different types or errors; thus it can take into account the record of previous responses made by the learner and several response parameters at once in making its decisions.

In short, the modern computer allows for a more complete adaptation of the teaching machine to the learner. It was used in an interesting manner in the Pask teaching machine where the "strategy of teaching"[6] is based upon a partly competitive, partly cooperative game. For example, the learner is asked a question; if he answers it correctly, the machine, through the intervention of the computer, presents him with a more difficult question: a competitive game. If the question is answered incorrectly, the machine presents a more simple question: a cooperative game. The computer thus "decides" upon the intrinsic composition of the programme according to pre-established criteria. Its strategy and the learner's responses are combined to determine the selection sequence from the available library information. The computer also can control the rate at which information is presented to the learner. As the learner punches cards, for example, more rapidly, the machine can increase the rate of presentation of the information up to a criterion limit. In the case of too many errors, the machine can slow down the rate of presentation.

This analysis has attempted to make explicit the requirements of complete teaching machine systems as the present state of the art appears to reveal them. As already mentioned, the implementation of many of these requirements can be extremely simplified by relying upon the learner to perform them, or upon simple devices; however, for certain types of teaching this is an undesirable solution to the problem of implementation.

Adaptivity

It has been said that "schools of education are institutions for programming people."[7] There may well be arguments between educators regarding this designation, but it *is* true that a student in education either learns how to teach or learns the subject matter that is to be taught. (There is, of course, much controversy as to the proper relationship between these two goals). It is equally true that complete knowledge and mastery of a subject does not necessarily make one a master teacher.

Teachers are, in the writer's opinion, adaptive teaching machines in the sense that they learn things both in their programming period in college and after they join the profession.

A teaching machine which is not adaptive — which is not, to some extent, a self-organizing *learning* machine — can be considered only a limited channel of communication between a teacher (who may not be a good one) and a student.

Adaptivity in a teaching machine system is the capacity of the machine and its associated programme to adjust, in one way or more, to the specific needs of the individual learner; thus it is probably the most critical feature of a teaching machine system. Each of the basic functions of the ten requirements outlined above is an explicit description of the way in which a teaching machine may be adaptive.

Passing Fad or Permanent Fixture?

Many educators wonder if teaching machines are just another educational fad. The answer to this question is obviously a matter of opinion and not one of fact, since evidence will have to be accumulated for several years to come. Certain facts argue for the possibility that teaching machines might be "more of a fixture than a fad."[8] Not all media of education are equivalent. The machine appears to have certain advantages over a book. It is the most controlled of all teaching conditions; and it is designed, ideally, to take the learner from a state of lack of knowledge to full knowledge in such a way as to suit his individual needs. A textbook does not always do this; in fact, in serving several purposes, or masters, it often must compromise each to satisfy all. The book is efficient for storing and making conveniently available large amounts of information; it has primarily a storage function and an access function. The teaching machine, on the other hand, serves a single purpose — teaching.

Most mass media suffer from their failure to make specific cues and responses clear (display function). In the usual format they do not require overt response; this is associated with the deficiency of eliminating the feedback loop which informs the learner of his own progress. With a teaching machine, the learner is in control, in that *his* responses determine what he does next within the pre-planned limits of the programme; thus there is feedback and adjustment of the learning situation to the needs of the individual.

Uttal considers that "the human tutor is a superb teaching mechanism, and the highly adaptable nature of the conversational interaction is apparently a very effective means of imparting information." He avers that those who share the enthusiasm for computer-based teaching machines do so because, "a computer allows us not only to simulate all other classes of teaching machines, but also to approach full simulation of the human tutorial process."[9] In short, it seems likely that, no matter how sophisticated the computer may be, nor how permanent it may become, its purpose is to aid the teaching process, not to monopolize it; its task is to enhance the efficiency of the teacher, not to replace him.

References

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