DEUS EX MACHINA

A Review of recent developments in Automated Teaching

Introduction

One of the most spectacular advances in education during the last two or three years is the teaching machine. These devices originated in the United States of America, possibly as a result of the development of automation, and it is safe to say that that country is way ahead of any other in the world in this field.

Hostility towards mechanical devices in the classroom stems surely from ignorance and conservatism among educationists. Nevertheless, as Mr. K. Richmond of Glasgow University avers in an article in the 'Times Educational Supplement' of 3rd February, 1961, 'We live in a world in which we are forced to acknowledge that for certain purposes, the extent of which cannot be foreseen, a mechanical device is often more efficient than the human brain.'

Definition

The teaching machine has been variously defined as "a means by which some aspects of instruction are made available to the student at his personal convenience," or "a self-instruction device," or "any device which presents material systematically while making efficient use of the principles of reinforcement."

A complementary system which has emerged and branched out in another direction is that initiated and developed by Norman L. Crowder, who is at present Head of the Training Systems Department of Education Science Division of U.S. Industries, Inc. The identifying feature of this system of "intrinsic programming" is that the material presented to each student is continuously and directly controlled by his performance in answering questions.

Function

Professor Skinner in a recent article in the "Scientific American" makes this point about the teaching machines: "Recent advances in the experimental analysis of behaviour suggest that for the first time we can develop a true technology of education. This technology, following the practice of the experimental laboratory, will use instrumentation to equip students with large repertories of verbal and nonverbal behaviour. Even more important, the instrumentation will be able to nurture enthusiasm for continued study. The instruments that will help our schools to accomplish all this are called teaching machines.... Like all useful machines, the teaching machines developed slowly from the need to do a job more effectively than it could have been done otherwise. They have evoked all the reactions, including the hostile ones, that we have learned to expect from a new kind of machine.... The purpose of a teaching machine can be stated simply: to teach rapidly, thoroughly and expeditiously a large part of what we now teach slowly, incompletely and with waste of effort on the part of both student and teacher."

Advantages

While many extravagant claims have been and can be made, both for the potential and for the actual success of the machine, there is no doubt that it has certain distinct advantages over traditional teaching methods. It is in a sense differentiation carried to the ultimate—every user can progress at his own rate and can check his progress as he goes along. One machine now on the market in America, for example, makes the following claims: 'Speeds learning process—suitable for most age groups and subject matter—simple to operate—trouble free—portable—requires no electrical connection'. One of the simplest mechanical aids in, for example, arithmetic is the number recognition machine, where a domino pattern is equated with a number up to six, and a light glows when the correct button is pressed. At the other end of the scale is the U.S.A.F. Troubleshooting Trainer which simulates conditions facing jet pilots, and which 'freezes' when the opera-

Mr. Leslie Proctor and Mr. W. G. Barnett have co-operated in the production of this interesting article on teaching machines—one of those topics that need more fact and less opinion in their evaluation. Members of the Johannesburg College of Education, they hope to produce in 1963 a Symposium Monograph on the subject, enlarging the present article into a pamphlet, which will be available to members of the public at a small charge. The present article offers not only a summary of the background development of teaching machines, but also an approach to some of the problems which these machines may present in use.

tor makes a mistake. A recent experiment carried out on a batch of R.A.F. recruits showed that there was a 39% saving in the time taken to learn elementary trigonometry over conventional classroom methods. Similar research has been carried out by the British Admiralty, the report of which is not yet available.

Contribution

At this stage it is rather difficult to decide what contribution the teaching machine has to make. What the machine does is to bring the student into vicarious contact with the mind of the person who composed the material to be learned, in the same way as the reader of a book makes contact with the mind of the writer, but under different circumstances. Just as one copy of a book can be read by many readers at different times or many copies of a book by many readers at the same time (all at their own speed of reading), so the machine can save time and labour by bringing the composer (or programmer, to give him his technical name) into contact with an indefinite number of students either at the same time or at different times, depending upon the number of machines available and even more important into individual contact with the students.

The function of the teaching machine is not identical with those of conventional visual aids. The use of visual aids does not constitute a new method of teaching—only a different manner of presenting and re-inforcing the material and amplifying and extending old methods. An illustration or drawing in a text-book (or for that matter in an examination) for example is merely a simplified version of, say, a slide film. Teaching machines differ in three important respects from the visual aids. First, continuous active response is required on the part of the student, with explicit practice, testing and correction of each step of material to be learned. Secondly, the student (or operant) is aware, at every stage of his work in the learning process, of the correctness of his response, leading him directly or indirectly to a correction of his errors, without which correction he cannot proceed to the next step or stage. Thirdly, the operant proceeds individually and at his own rate.

It is in these three fields that the teaching machine seems to offer peculiar advantages over ordinary classroom conditions.

A feature not always encountered in the usual methods is that the machine does not merely present something to be learnt; it induces sustained activity by means of reinforcement, which will be discussed later. Of this aspect, Skinner says: "The student is always alert and busy. Like a good tutor, the machine insists that a given point be thoroughly understood, either frame by frame, or set by set, before the student moves on.... Lectures, textbooks and their mechanized equivalents, on the other hand, proceed, without making sure that the student understands, and they easily leave him behind. Like a tutor, the machine presents just that material for which the student is ready. It asks him to take only that step for which he is at the moment best equipped and most likely to take. Like a tutor, the machine helps the student to come up with the right answer... with techniques of hinting, prompting, suggesting and so on." The Crowderian machine, in fact, is able to evaluate and correct responses immediately they are made.

History

Although teaching machines are a comparatively recent development, their history goes back some thirty-odd years. The ancestry of teaching machines may properly be traced to Sidney L. Pressey, a psychologist of Ohio State University, who in 1924 constructed a machine for testing, consisting of questions coupled to multiple-choice answers. If the student obtained the right answer by pressing a button, he could move on to the next question. If he was wrong, the machine registered the error and he had to try again until he got the answer right. Pressey realised the potential of his machine for teaching, but it had two patent weaknesses. It did not employ the principles of programming, upon which the success of the machine as a teaching device rests; and as a multiple choice device, it appeared to be limited to recognition response rather than allowing the operant to record his answer in the usual way.

Later, machines were built which employed constructive responses, but in some of these, automatic scoring had to be dispensed with at the expense of more extensive response repertoires, where the student himself judged the correctitude of his answer by comparing his own answer with that given by the machine after he had given it.

Pressey built his machines in accordance with existing knowledge of the learning process. Since then, great advances have been made in the study of this branch of pedagogy, many of them due to the energy of Professor Skinner of Harvard. Briefly, the success of Skinner's machine depends upon, besides adequate programming, the shaping of operant behaviour which is brought about by reinforcement. In an important paper published in 1954, Skinner maintained that control in our present educational system, no less than that of fifty years ago, is aversive—the two systems differing only in the forms of aversion. In other words a child learns in order to avoid "the consequences of not learning"; fifty years ago, these were the birch rod, and at the present time such minor aversive events as displeasure of teacher or parent, ridicule of peers and low marks. Furthermore, the time lag between response and reinforcement in the normal classroom situation is such as to destroy most of the learning effect. The teacher is, for obvious reasons, unable to reinforce at each step in the child's work under normal classroom conditions, and the reinforcement takes place at infrequent intervals, with a resulting loss of efficiency in the learning process. Convinced of this, Skinner decided to attempt to produce an alternative learning system with what he considered more adequate reinforcement. He did this by studying the application of behaviour stimuli to pigeons. After several years of laboratory study and research, he discovered that behaviour patterns could be induced, given the right kind of reinforcement at the right time. "Simply by presenting food to a hungry pigeon at the right time, it is possible to shape up three or four well-defined responses. The results are often quite dramatic. One can see learning taking place."

Armed with the results of his researches, which were in reality extensions of the Pavlov experiments, and supported by experience of machines used during the war for instruction of military personnel (many of them elaborate and costly affairs, indicating the faith that the authorities pinned on the efficacy of such machines) Skinner applied himself to the development of machines which he confidently expected would reduce inefficiency in the learning process. The success of these and other attempts cannot be gauged at the moment. Much more time and energy will have to be spent in observing and testing the results of learning under these revolutionary conditions.

Programming

Mention must be made at this point of a factor upon which Skinner maintains the whole success of teaching machines lies—adequate programming.

Programmed instruction is essentially a refinement of ordinary teaching methods; it is an analysis of the various steps by which material may best be conveyed to the pupils, its advantage being that it can utilise the intuitive understanding of their subjects of the most efficient teachers. The effectiveness and use of such things as the printing press and the fountain pen (as with other machines in a much wider sphere, notably wireless and television) depend not upon the machine itself but upon the user of that machine and upon the use to which the machine is put. The most elaborate machine will be as good or as bad as the human mind supplying it with the material to be presented to the operant in a mechanical way. Programming in a sense is specialised preparation of lesson material to suit the machine, and as such demands that much time, thought and technical ability be spent on it. The difficulty of adequate programming is acknowledged, and Robert Glasser, in a recent (1960) article admits that "the fact that it is a difficult and aversive task to programme material, and a much easier task to build the accompanying hardware is indicated by the fact that at the present time machines outnumber programmes by a large factor."

Another interesting comment is that by Robert E. Slaughter, Senior Vice-President of the McGraw-Hill Book Company, who has this to say: 'Programmed instruction will provide new publishing opportunities. Programmed materials intended for supplementary use or for independent study are the most likely to win wide acceptance in the foreseeable future.

"Programmed instruction will also affect all school materials—printed, audio and visual—by influencing their preparation. Objectives will be established specifically; subject matter will be carefully structured; the materials will be intensively tested in the preparatory stage. Finally, programmed instruction will require the text-book industry to study carefully the developments of this new technique, and to find ways of helping educators who wish to introduce programmed materials and to use them effectively.

"Programmed instruction is based on established learning theory, and has real significance for the textbook publishing industry. It is a new development and the textbook industry can and should make an important contribution to its needed and growing sophistication as a new and promising tool in education."

There are many problems still to be resolved in programming, for example the size of the steps in the programme, the amount and nature of the prompting, which are essential parts of automated teaching. Prompting is usually of a semantic or contextual nature. The following examples abstracted from an article by Lumsdaine (1959) are enough to show the nature of this means of developing the desired response patterns.

(i) By analogy or example
e.g. Just as a rise in temperature increases gas pressure, a rise in filament temperature will ...?... electron emission from the filament of vacuum tube.

(ii) By word habits
e.g. When we start to trace a signal from the antenna to the viewing tube, the ...?... component we encounter is the R F detector.

(iii) By cues from preceding items
e.g. (a) A ...?..., used to control voltage, consists of two coils of wire wound on a core.

(b) Input and output voltages of a transformer are governed by the number of turns of wire in the primary and secondary ...?...

(c) The ratio of the number of turns in the ...?... coils determines the ratio of input and output voltages.

Of the size of the steps to be used, Skinner says: "By making each successive step as small as possible, the frequency of reinforcement can be raised to a maximum, while the possibly aversive consequences of being wrong are reduced to a minimum."

A somewhat different approach from that of Skinner is what has been formed by Crowder "intrinsic programming". This technique has been modelled on the traditional pupil-teacher relationship in the class room. The characteristic feature of intrinsic programming is that the pupil responds to what the teacher presents; the teacher modifies the presentation of material on the basis of what the pupil does. Intrinsically programmed material correctly prepared will permit this interaction without a live teacher. The main features of the Crowderian system are clearly explained in the following quotation from the periodical 'Programmed Instruction' dated April, 1962: "If (the student) chooses the right answer he is automatically presented with the next paragraph of material and the next question. If he chooses the wrong answer he is automatically presented with material written specifically to correct the particular error he has just made. At the end of this correctional material the student will, in the simplest case, be directed to return to the original presentation to have a second try at the original question. Or the choice of a wrong answer may lead the student to a 'sub-programme' or subsequence, explaining the originally troublesome point in smaller steps or via a different approach."

Role of the Teacher

What is the role of the teacher under this machine-orientated régime? Are his services redundant? Does he step back and assume a minor role? With few exceptions, formal instruction in the various stages of the subjects for which programmes have been evolved—and these cover such widely differing subjects as Russian, trigonometry and musical appreciation—is still necessary. It is doubtful whether any machine will ever be able to take over the task of the teacher with his multifarious roles of guiding, counselling, helping to shape judgments, ethical, religious and moral standards and aesthetic appreciation. Skinner's reply is: "There is more important work to be done (than marking a set of papers in arithmetic)—in which the teacher's relations to the pupil cannot be duplicated by a mechanical device.... Mechanical devices will eliminate the more tiresome labours of the teacher but they will not necessarily shorten the time during which he is in contact with the pupil." And again: "In assigning certain mechanizable functions to machines, the teacher emerges in his proper role as an indispensable human being. In return for his greater productivity he can ask society to improve his economic condition."

Widespread use of teaching machines would also help to alleviate the shortage of teachers, especially in specialist subjects. The fact that the machine is neutral cannot be denied. The patience of a machine is inexhaustible, nor is it subject to the same antipathies and emotional reactions as a human teacher is.

A somewhat extremist view is that of Dr. Galanter of Pennsylvania who contends that it will eventually be possible to build machines which will replace human beings as teachers, and even envisages a machine which will be self-programming. On the other hand, Mr. K. Austwick of Sheffield University has rejected any suggestion that the machines should be used as substitutes for teachers. In The Times Educational Supplement, he is reported as saying: "In a dire emergency (machines) would be better than having no teachers at all and they would be very useful in overseas countries where there was a fantastic shortage of teachers."

Cost

The cost of educational equipment looms large on the horizon of the administrator or politician, who is closely concerned with providing sound education as cheaply as possible. Teaching machines vary a great deal in price, depending upon the size, subject and kind of programme. But why should automation be denied to children of parents, most of whom can afford a washing machine, mixer, polisher, refrigerator and so on in their own kitchens. One model, advertising itself as 'cheat-proof, package loaded, adjustable and silent' costs $19.84; the Foringer Teaching Machine, selling at $80.00 some months ago has been taken over by the Ferster Tutor, on sale at $6.00. Larger, more complicated machines, such as the Crowder machine cost anything up to R900. Other types of machines can be and are being designed and built by various enthusiasts on a do-it-yourself basis.

Paradoxically, these machines are likely to make greater advances in the fields of commerce and industry than in education, largely not only because they are more efficient but also because they offer significant economic advantages over traditional methods.

The pupil-machine ratio has not yet been determined, but what is certain is that an adequate number of programmes must be available, but that again will no doubt be determined by experience and experiment in the class room.

South African Needs

Of the application of automated teaching to the needs of the African continent, and more particularly of South Africa, both at the formal and non-formal levels, much could be said here that would be, at this stage, mere conjecture and hypothesis. That teachers' associations, N.I.P.R. and other scientific groups should undertake the careful study and investigation of existing modes of automated teaching and its possibilities in this technological age and that this should be done immediately is axiomatic. A first step in automated teaching has been taken in the institution of a language laboratory at the University of the Witwatersrand under Professor Lanham, in the work of Professor Cole of the

Department of Bantu Studies and the energy of Mrs. Whyte in the Bantu Literacy Company.

The aims of this review will have been fulfilled if there has been brought to the notice of educationists the existence, the nature and the functions of the teaching machine and the possibilities of the new educational technology. Certain it is that this new age will provide unprecedented opportunities for an intelligent and democratic partnership in which education, psychology, industry and technology must all play their part.

There are many questions and problems concerning teaching machines which have not been touched on in this article for the simple reason that few opportunities exist for on-the-spot study of the nature and success of machines in South Africa. The editorial board would welcome any information about teaching machines that are in existence or have been proposed in this country. It is the intention of the Editorial Board of 'Symposium' to promote research, demonstrations, evaluations and discussions on the place of the teaching machine in South Africa.