J. A. M. Howe

A New Deal?

Using computers to teach children with communication difficulties

In the very early days of teaching machines, B. F. Skinner was once asked by a somewhat hostile group of colleagues how he visualized them being used in school. "Well," he said, with a bit of gleam in his eye, "the bell rings for the end of recess, a boy comes running into the empty classroom, hurls his jacket into the corner, and sits down eagerly to the machine..." Skinner was dramatically confident of the humane effect of his schedules of reinforcement. Howe has the same confidence in the computer as teacher, for many good reasons, and especially in its potential to unlock the mental processes of children with specific difficulties in communication. He illustrates some of the potential and fascination of computers that use special devices to offer the right kinds of feedback to a curious child. He sets out in careful steps the necessary theory of mental representations that has enabled him to focus on just those tasks, like writing a simple program for the computer itself, that persuade children with mild mental handicaps, maladjusted and even autistic children, into flower as communicators.

It is not difficult to envisage a computer being used by a physically or mentally handicapped child as an aid in composing language. The child could form sentences by manipulating some kind of pointing device to select appropriate words from a list displayed in menu form on a TV screen; by selecting individual letters, the child could form new words, and so on. In contrast, just because we have a very impoverished understanding of the process of communication, it is very much harder to envisage a computer being used to teach a handicapped child the underlying skills of successful composition. To do this we have to take one step back in the design process and, before proceeding with the technological aspects, tackle issues that concern the organization of teaching materials, choice of teaching strategy and so on.

Computers can teach where others fail

Why should we bother to use a computer to teach children with communication difficulties? The answer is that there is a small but growing body of evidence which suggests that computer-based schemes may succeed where conventional teaching methods have failed. For example, at the Australian National University, Macleod and Proctor (1976) have been teaching basic handwriting skills to severely handicapped children. Their set-up comprised a display screen and a special pen which the child used to trace along faint lines (that is, guidelines) drawn on the screen by the computer. To write out a word in cursive script — for example, his name — the child had to learn to make a particular sequence of pen strokes in a pre-determined order and direction and within a predefined accuracy. Each time he made a correct pen excursion, the guideline on the screen was brightened to convert it into a pen stroke. Any incorrect pen movement was ignored and the child's attention brought back to the start of the particular guideline. The degree of difficulty of the task could be changed, for example, by altering the segmentation of the handwriting so that continuous guidelines for letters or even for short sequences of letters were presented, instead of sequences of individual strokes.

The advantage of Macleod's approach is that the learner can self-correct his writing actions until success is achieved, by comparing his own productions with those which he is expected to make (the guidelines). Its effectiveness is hinted at by the results of a short series of pilot trials. Three pupils who had not learned to sign their names as a result of conventional teaching were able to do so fluently, within one to four hours. More recently, the method has been adapted successfully to teach blind children handwriting, using auditory feedback to signal their deviations from the guidelines.

At Edinburgh University, we have developed a computer-based system for teaching handicapped children word attack skills (Howe *et al.,* 1978). It is a phonic method: consonants and vowels are taught by getting a child to associate an unknown letter shape with a sound uttered when naming a familiar object. The set-up comprises a computer-controlled slide projector and a pressure sensitive screen (Howe *et al.,* 1974). Teaching materials in photographic slide form are back-projected on to this screen. For example, to teach the initial consonant *c* the child might be shown an exemplar slide containing a picture of a cat and the letter *c* in its initial position in a word *c*——. The child's task is to say aloud the name of the object, and to associate the initial sound with the unfamiliar letter shape. This exemplar would be followed by a series of slides presenting variants of this task. Some of them would present a picture of a familiar object and a choice of initial consonants, including the *c;* others would present two or three objects, with the name of one beginning with the initial consonant *c.* When the child registers a choice by pressing the area of the screen containing the picture or letter, the co-ordinates of the screen position are read by the computer, which uses this information to work out how the child has responded. In practice, several initial consonants like *b, c, t,* and *d* are taught by the same batch of slides, so the child compares and contrasts the unfamiliar letter shapes when making a choice.

A particular feature of our teaching strategy is the feedback of information. When children make a wrong response by, for example, selecting the wrong picture to match a letter, they are given two kinds of information: they are shown which letter or letter combination corresponds to the choice actually made and which picture corresponds to the given letter, that is, the choice they ought to have made. The effectiveness of this strategy is confirmed by the results of laboratory trials carried out with a small group of non-reading handicapped children drawn from special schools, which show that eventually they were able to use word attack skills to decode the names of unfamiliar objects. Observations in their classrooms confirmed that these skills were transferred to classroom reading tasks, in the absence of pictorial materials, laying the foundation for higher-level reading skills.

At the University of Calgary, Hallworth has been undertaking a program of research in collaboration with the Vocational and Rehabilitation Research Institute (Hallworth and Brebner, 1978). As in our work, Hallworth has developed a variety of special-purpose input-output devices to ease the problem of interacting with the computer, for example touch screen, button box, POSSUM keyboard, and speech synthesiser. Working with the mentally handicapped, he has devised two teaching schemes, one dealing with reading and one with social arithmetic. His approach is to organize teaching materials into units dealing with particular skills or concepts, to give immediate reinforcement after each response, and to provide appropriate remediation when the pupil gives the wrong answer. Thus the social arithmetic scheme introduces skills needed for handling money in everyday situations. After covering counting skills, simple addition, subtraction, place value, and the concepts of more and less, pupils are introduced to money. They are taught to recognize individual coins and their values, to make sense of groups of coins, and finally to deal with paper money. After tackling more difficult addition and subtraction problems involving carrying and borrowing activities, they are then taught how to handle purchasing, budgeting, and other money-handling situations. The results of controlled studies (Sandals, 1973; Strain, 1974) suggest that this approach is an effective way to teach the mentally handicapped how to deal with these kinds of everyday situations.

The success of these studies can be attributed in part to three important features of the computer. First of all, from the children's point of view the computer is a familiar, exciting device which can solve very difficult problems, such as guiding a ship to the far reaches of outer space and back again. If it can help the astronaut, surely it will be able to help them? In practice, they find it untiring, predictable, always saying the same thing in the same way; never bored, never angry, and ever obedient — in fact it has all the characteristics which most people lack but which are reckoned to be highly beneficial when teaching backward children.

But whether or not the computer will actually help a child depends not only on his or her attitude to it, but also on the kinds of activities which it offers, and his understanding of what he is required to do. This brings us to the computer's second feature: working with it disciplines teachers in the sense that they have to produce both a precise description of a task *and* an effective procedure for executing it. In this case, the activity of programming serves as a metaphor for teaching, making the point about the need to be precise and explicit at all times when dealing with a system — albeit computer or child — which has little or no inner ability to interpret a teacher's wishes and intentions.

Thirdly, the teacher is able to take advantage of the computer's capacity to handle complex teaching procedures which he or she could not cope with under group or class teaching conditions: for example, those classes of tasks requiring the continuous feedback of information to individual children in response to their actions.

Learning to communicate — an analysis

When a teacher constructs a program, wittingly or unwittingly he or she will have built into it a teaching strategy which reflects a view about how children learn. So the program can be assigned a position along a dimension anchored at one end by the view that children "learn by being told," and at the other end by the view that they "learn through discovery." This suggests that besides having a practical objective a program can be interpreted as testing the effectiveness of a particular teaching strategy. For example (a negative one), the carefully developed computerized drill-and-practice programs developed during the 1960s at Stanford University (Suppes and Morningstar, 1969; 1972) did little to improve children's arithmetic performance, revealing the weakness of the reinforcement regime which had controlled the teaching.

This point brings us to the heart of this paper — the teaching strategy issue. To make sense of the approach which we and others are following we will have to back-track and expose our view about how children learn. This can best be outlined in the following three premises:

1. Learning is gathering information, which is represented in complex mental structures. Collectively, these structures constitute our knowledge of the world. Besides storing information about physical objects, these mental structures represent abstract concepts and relationships which are derived from this accumulated information by the operations of generalization and differentiation processes.

2. Gathering information comes about through activity. This includes ex-

ternal actions in the physical environment (like play) through which information about objects, events and people is gathered *directly;* and internal actions upon the mental representation of the environment (for example, classifying and inferring) by means of which information is gathered *indirectly.* Until the child can use these latter reflexive methods of getting information that lies beyond what is directly represented, his information-gathering activities will be severely constrained.

3. Motivation is a prerequisite of activity. We assume that a child has a built-in drive to explore. Through his or her actions in the environment, information about particular objects, particular events and particular people becomes embedded in mental structures. As these mental structures develop, their very existence will begin to influence the child's actions, introducing the kind of consistent behaviour associated with a lively, intelligent child. Conversely, impeding a child's spontaneous activity will inhibit the growth of mental structures, and the child's level of motivation will diminish as he or she gets out of step with others.

Turning now to the relationship between learning and communicating, we believe that many communication difficulties can be attributed to weak, impoverished mental representations. Our argument goes as follows. We begin by assuming that communication is the exchange of meanings and intentions through the medium of language, either directly in speech or through writing and reading. In other words, language is a window of the mind; it enables a speaker or writer to talk about his thoughts and intentions because it is mapped on to his pre-linguistic system of representation. The words used take on in another's mind the sense intended to the extent that they invoke there similar knowledge. Much of the time, individuals are in contact with their peers, so their pre-suppositions about shared knowledge are usually justified; but if an individual is trying to communicate with a population whose system of internal representation is different from his or her own in important respects (young children, for example), he is not entitled to assume that his words will make the same sense to them. Indeed, recent research in child development suggests that normal children's competence as assessed by classical Piagetian tasks has been underestimated, because there exist conflicts between the interpretations which children spontaneously accord to some task and the experimenter's intentions about its interpretation (see, for example, Donaldson,1978). How much more of a conflict must there be when one is attempting to communicate with a child whose representation of reality is even less complete!

Feedback *versus* playing the whistle

Instead of conforming to the rules of the game as established by the teacher, such a child is likely to define his own rules. For example, a certain pupil who had been described by his teacher as stupid and disruptive in class displayed a great deal of ingenuity when faced with a drill-and-practice arithmetic program (Cassels and Howe, 1971). Presented with the addition sum

12 + 7 = ?, he responded with 16. The system printed NO, TRY AGAIN; but instead of giving an alternative reply, he simply pressed the teletype key which tells the computer to read in an answer. This nil response was accepted by the computer, which printed NO, THE ANSWER IS 19. Having in this way learned how to get the correct answer after making an error, his next ploy was to press this response key as answer to the *first* presentation of a sum, thereby getting the machine to tell him the correct answer immediately. At this point, the program was modified to force him to give an answer. Failure to comply elicited the message, YOU MUST GIVE AN ANSWER. His reaction was to type a random sequence of digits instead of the correct answer. For example, in reply to the question 9 + 12 = ?, he responded 18. When asked to try again, he typed in 123!

What we have learned from this kind of behaviour is that to teach such a child, every task must be couched in terms familiar to him, every instruction must be made as explicit, as simple, and as unambiguous as possible, and every error must be accompanied by information explaining what was wrong with his answer and why. Indeed, we believe that feedback of information about outcomes is particularly crucial, since it alone enables a learner to check, change, and up-date the content of his internal representation. For convenience, we call a learning situation involving information feedback *a reactive learning situation.*

An early example of the effectiveness of a reactive learning situation is the study by Tait and others (1973) of learning to multiply. Working with normal children, their objective was to compare reinforcement feedback with information feedback. The latter took the form of six questions asked after a pupil made two errors. For example, if a pupil made a mistake in the second digit of the answer to the sum 764 x 9, the computer would print out the following questions, each of which required an answer. If incorrect, appropriate information (shown in the right-hand column) would be supplied by the computer before it moved to the next question:

Question	**Feedback (for wrong answer)**
WHAT SHOULD YOU HAVE CARRIED?	NO, IT SHOULD HAVE BEEN 3
WHAT NUMBER X9 NOW?	NO, IT IS 6
WHAT IS 6 X 9?	NO, 6 X 9 = 54
NOW, ADD ON THE CARRY	NO, 54 + 3 = 57
WHAT DO YOU PUT DOWN?	NO, PUT DOWN 7
WHAT DO YOU CARRY NOW?	NO, CARRY 5

In contrast, reinforcement feedback yielded the following output:

6 X 9 + CARRY = 57 PUT DOWN 7 CARRY 5

The results of this study were clear cut: the performance of pupils given information feedback was significantly better than that of pupils given reinforcement feedback.

Preliminary evidence of benefit

Since theorizing without evidence of practical benefit is an empty pursuit, we will briefly examine some evidence which supports our case. The only caveat is that few studies have dealt directly with communication difficulties; much of what we know has been learned from accidental observation.

We will be considering a less familiar way of using computers to teach children, namely building computer models. The approach followed is to use the computer to simulate a system — for example a picture-drawing system, a tune-composing system, or a sentence-generating system. Such a system can indeed be explored by a pupil because programming provides the language needed for talking about the process of drawing a picture, or composing a tune, or generating a sentence. Suppose that the programming language provides commands which can control the movement of a mechanised pen around a drawing surface, for example FORWARD (a distance), BACK (a distance), LEFT (a rotation), RIGHT (a rotation). These commands can be used to make a procedure which describes the process of drawing some object. The program which describes how to draw an equilateral triangle is as follows:

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DEFINE "TRIANGLE" (This tells the computer that the object being
                                        described is named TRIANGLE.)
        d: 1 FORWARD 500
        d: 2 RIGHT 120
        d: 3 FORWARD 500
        d: 4 RIGHT 120
        d: 5 FORWARD 500
        d: 6 RIGHT 120
        d:   END
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When this description of the process of drawing a triangle is entered into the computer and executed by it, the drawing will be produced. This program can be stored in the computer's memory, and can be re-used at will by calling it by name.

Suppose now the child wants to draw a house: all he needs to do is break down the house into two components, namely square and triangle. Having worked out how to draw a square in terms of basic pen movements, and having defined and stored the corresponding program, he can define a new object called *house* which can be described in terms of a call to the object named *square* and a call to the object named *triangle*. Calling a procedure by its name in this way is a good metaphor for the process of communication, since the name invokes knowledge shared between the child and the computer (namely, the description of how to draw the object).

We have found that getting a child to start experimenting with drawings is a valuable activity. Since the movements of the drawing pen correspond roughly to his own body movements through space, he can try to "act out" the role of the pen to help him work out how to construct a particular shape, or how to correct a drawing that has gone wrong. This description illustrates the reactive nature of the computer modelling activity.

An autistic boy

Two of my colleagues worked with a seven year old autistic boy, using a version of the drawing system described above (Emanuel and Weir, 1976). As drawing device they used a computer-controlled toy — a small robot device called a "turtle" which was devised by Papert at MIT. To simplify the problem of entering commands into the computer, they adapted a button box. Each button, labelled with an icon to indicate its function, represented a turtle command, say FORWARD 200. Pushing a button caused it to light up, as well as commanding the turtle to execute the action. The button's lamp was extinguished when the command had been executed. Some buttons were masked off during the early stages of learning to reduce the complexity of the task.

When the project began, the autistic boy was biddable and could carry out simple verbal instructions. He could also utter some word sequences, in parrot fashion, to express his needs, such as "more paper please." Socially, he was quiet and gentle, avoiding eye contact, and responding to questions in a stilted way. His case notes were full of the following kinds of statement: "has never made a spontaneous statement to us, except under stress," "speech has to be prompted every time," "no spontaneity — has to be asked again and again."

Work with non-speaking autistic children had previously been undertaken by Colby, who attempted to stimulate their language development with games which involved associating computer-controlled displays of pictures and letters with their sounds, as a way of building up meanings (Colby and Smith, 1971). He judged that the language ability of 13 out of 17 of his autistics had improved after 50-100 half-hour sessions with the computer. In contrast, our autistic pupil began to make spontaneous vocalizations after only 7 one-hour sessions, spread over a period of six weeks. Videotapes of his activities show him beginning to predict the turtle's actions on the basis of a growing understanding of the relationship between his own actions, pushing buttons on the control box, and the turtle's behaviour. Soon he begins to mimic the turtle's actions, as a rudimentary form of communication. Finally, and dramatically, he begins to use speech fragments spontaneously to communicate his intentions to others. This was no short-lived phenomenon: about a year later he was transferred out of the autistic unit thanks to sustained improvement in his ability to communicate with others.

Class clowns

Another example, reported in detail in Howe and O'Shea (1978), is the case of an 11-year old boy who had been diagnosed as "dyslexic." Although receiving regular remedial help with reading and writing, he was making little progress. In the classroom, he was regarded as a buffoon: given easy questions, he would get the answers wrong and clown for the entertainment of his classmates. After spending four months writing programs to draw geometrical patterns, he began to realise that he actually understood what he was doing. Furthermore, he discovered that he could explain how his programs worked to his classmates, and that he could help them with their programming problems. As a result, he was given the nickname "Teach;" his parents and class teacher noticed the improvement in his self-confidence, and his work at the remedial centre showed significant improvement which his remedial teachers attributed to his programming activities.

This is by no means an isolated instance. Papert and others (1978) report an identical case — a boy called Ray who had been diagnosed as having a learning difficulty. Like our boy, he played the rôle of class clown; his reading was extremely poor despite individual tutoring. Unlike our programming activity, which is organized into small units, the problem Ray was set to work on was the larger one of writing programs to draw his initials. Not surprisingly, he could not cope, and began to miss sessions. The breakthrough came much later when his teacher realised that Ray could only handle one task at a time. Instead of being asked to construct objects from basic drawing commands, he was given prewritten programs for constructing classes of patterns, and spent a number of sessions experimenting with them. When interviewed, his classroom teachers reported a gain in self-confidence, and a marked improvement in his writing.

Finally, in a study involving writing programs to generate tunes, Beckwith (1975) describes a boy called Brian who had been diagnosed as a slow learner and was repeating Grade 8. He was characterised as shy, awkward, and a butt of amusement in the class. Given a little encouragement, he experimented with the music system. As he began to understand the computer commands, and became increasingly involved, he could not help but make progress. Back in class, his teachers reported that he had broken out of his shell and had risen in his classmates' estimation. He had become vocal and showed pride in his own work and opinions.

Although the evidence presented above is fragmentary, and any conclusions must remain tentative, we can at least take issue with those who argue that introducing computers into education will have a de-personalizing effect on those who come into contact with them. Our experience fails to support this view; there is nothing more de-personalizing than not being able to communicate. Indeed, we believe that the time is now ripe for a new deal for the handicapped through the introduction of computers in special education.

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REFERENCES

Beckwith, S. "The Interactive Music Project at York University." *Final Report* for the Ontario Ministry of Education, Toronto, 1975.

Cassels, F. and Howe, J. A. M. "Errors in Arithmetic." *Bionics Research Reports: No. 5,* School of Artificial Intelligence, University of Edinburgh, 1971.

Colby, K. M. and Smith, D. C. "Computers in the Treatment of Nonspeaking Autistic Children." *Current Psychiatric Therapies,* 11, edited by Masserman. New York: Grune and Stratton, 1971.

Donaldson, M. *Children's Minds.* Fontana, 1978.

Emanuel, R. and Weir, S. "Catalysing Communication in an Autistic Child in a LOGO-like Learning Environment." In *Proceedings of the 2nd Conference on Artificial Intelligence and the Simulation of Behaviour.* Edinburgh: Department of Artificial Intelligence, 1976.

Hallworth, H. J. and Brebner, A. "Computer Assisted Instruction and the Mentally Handicapped: Some Recent Developments." Paper presented to the 16th Annual Convention Association for Education Data Systems, Atlanta, Georgia, 1978.

Howe, J. A. M., Barker, P. J., Noble, H. M. and Salter, S. H. "Programming a Touch Screen Device." *Management Informatics,* Vol. 3 (1974), pp. 69-85.

Howe, J. A. M., Beattie, A., Cassels, F., Johnson, J. and Anderson, A. "Teaching Handicapped Children to Read in a Computer-Based Learning Environment." *D.A.I. Research Report No. 57,* Department of Artificial Intelligence, University of Edinburgh, 1978.

Howe, J. A. M., and O'Shea, T. "Computational Metaphors for Children." In *Human and Artificial Intelligence,* edited by Klix. Berlin: Deutscher Verlag, 1978.

Macleod, I. D. G. and Procter, P. "A Dynamic Approach to Teaching Handwriting Skills." Unpublished research report, 1976.

Papert, S., Abelson, H., Bamberger, J., di Sessa, A., Weir, S., Hein, G. and Dunning, S. "Interim Report of the LOGO Project in the Brookline Public Schools." *A.I. Memo 484,* Artificial Intelligence Laboratory, MIT, 1978.

Sandals, L. H. "Computer Assisted Learning with the Developmentally Handicapped." Ph.D. Thesis, University of Calgary, 1973.

Strain, A. R. "Computer Assisted Instruction in Social Arithmetic for the Retarded." M.Sc. Thesis, University of Calgary, 1974.

Suppes, P. and Morningstar, M. "Computer-assisted Instruction." *Science,* Vol. 166 (1969), pp. 343-350.

Suppes, P. and Morningstar, M. *Computer-assisted Instruction at Stanford, 1966-68.* New York: Academic Press, 1972.

Tait, K., Hartley, J. R. and Anderson, R. C. "Feedback Procedures in Computer Assisted Instruction." *Brit. J. Educ. Psychol.* Vol. 43 (1973), pp. 161-171.