NEWS AND VIEWS

Programs for Learning to Think

If Dewey was right that we learn by doing, and by thinking about what we do, then the goals of educational innovation are clear. We must invent better things to do in educational establishments and better ways of thinking about ourselves doing them. One aspect of current work in artificial intelligence which was not mentioned in the Science Research Council's recent Lighthill Report on the subject (see *Nature*, **243**, 318 ; 1973) is the role of computers in school education. The possibility that children of the ages of about ten and upwards could learn to program computers to control toy vehicles, draw geometrical figures, and compose music or poetry is at the heart of the LOGO project, which is Seymour Papert's response to Dewey's ideas.

Papert's writings on the subject are rather scattered, and not always easily available, though they can be obtained from the Artificial Intelligence Laboratory at MIT, and some have been published, for example in *Mathematics Teaching* (No. 58, 2 ; 1972) and in the proceedings of the NUFFIC Summer School, *Process Models for Psychology* (edited by D. J. Dalenoort, 1 ; Rotterdam University Press, Rotterdam, 1973). The essential features of the teaching project are that children in an ordinary American grade school have been introduced to computing by learning a simple language, LOGO, which they can use to control a turtle-shaped vehicle, with a retractable pen to draw on the surface on which it runs. Alternatively, they can draw or write text on a visual display, or control a bank of resonators to make music, or indeed operate any other device of an electromechanical kind.

Part of a typical beginning turtle program might, for instance, be a procedure to draw a triangle, as follows:

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TO TRI    :SIDE          1. FORWARD   :SIDE
2. RIGHT 120                  3. TRI  :SIDE
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Here the numbered lines are instruction statements, for example line number 2 instructs the turtle to turn clockwise through 120 degrees. In statement 1, FORWARD is an instruction to move forward. The colon indicates that what follows is not a literal but a name, in this case of a variable indicating the number of units to move. At the head is the name of the procedure, TRI, prefaced by TO which indicates that what follows is a definition, that is in this case how to draw a triangle. In the example, if a value of the procedure parameter SIDE is made available, for instance, by calling the procedure with the statement TRI 100 then the turtle will continually trace an equilateral triangle of side 100 units, by re-entering the procedure recursively from statement number 3.

The notion of a recursion in which a process is defined partly in terms of itself is well known to be difficult even for adults. In this project, though, children of a tender age come to grasp it not by having been instructed in the arcane hieroglyphs of algebra, but by controlling a toy vehicle. By starting with intuitions and concepts of movement and space which are real and immediate to children, and by giving them a symbolism that relates as closely as possible to these intuitions but which is nevertheless formal, one can introduce them to powerful ways of designing processes. In a sense the processes children design are rather like essays. The difference is that in LOGO not only can they extend the language themselves, but when they write an essay it is actually executed by the machine. This leads not only to a deeper understanding of the logical consequences of what they write, but opens up new worlds of surprising discoveries. For example, writing as a child might, FORWARD :SIDE +1 as statement 1 in the TRI procedure creates a spiral triangle. Children can thus gain an understanding of notions such as length and angle from the interplay between the symbols they generate and the real world, but they can soon experiment with the more complex ideas of variable, vector, state, and even quite advanced matters such as procedures and recursion, and in doing so make discoveries about the meaning and power of these ideas.

The point of starting with a compatible and immediate symbolism as a means for thinking about the world is important enough. But perhaps even more important is that in doing this children extend their own thought processes. In particular as they make mistakes, the logical consequences of the programs they type into the computer are demonstrated to them in the behaviour of the device they are trying to control. No teacher writes 0/10 in embarrassing red pencil on their exercise book, or tells them they have failed. In trying to draw a triangle, for instance, they might write RIGHT 60, and thus produce a figure which is not a triangle but a hexagon. They project such mistakes onto the program itself, and set about debugging it. In order to do this they necessarily have to acquire a deeper understanding of the process they are trying to create. Thus the gap between the desire and the fulfilment is bridged by the children debugging their own thought processes and coming themselves to grasp fundamental concepts of logic and process.

Although the project has produced no statistical comparisons with more conventional teaching methods, and any scholastic improvements one might see may be due to Papert's engaging personality and his interest in the children, it is difficult to argue against the need to invent new ways of thinking about the world if intellectual progress is to be made; and work in artificial intelligence has gone a long way in capturing the art and science of formally describing and using knowledge. The LOGO project is grounded in the understandings of epistemology that have emerged from the MIT Artificial Intelligence Laboratory, and starts from the idea that children as well as adults can benefit from expressing knowledge formally. The knowledge in their programs is applied to the design of processes which will do things that interest them, and the interplay between the symbolism and its execution provides not only for discovery but for thinking about how the processes work, and for thinking about thinking.

from our Experimental Psychology Correspondent