Microcomputers and Cognitive Development: The Need for Research

by Lois Baron

Introduction

The microcomputer is rapidly making its way into North American homes and schools. Microelectronics has created a tool with widely accessible, multifaceted capabilities. It can, for example, produce graphics that are very life-like in nature. Communication between the microcomputer and the individual operating it can be an active, interactive process. The microcomputer can even bring to individuals capabilities of a non-computing nature. These are only a few of the functions of the microcomputer that have softened the 'computer' in its name and made it a device capable of being used by even very young children.

The pace of the microcomputer's introduction into society, and particularly into schools, has been very fast. Researchers must grasp the moment *now* to study the use and development of this new, sophisticated medium. Doing so at this time may influence the direction of microcomputers in education. It will, hopefully, prevent misuse and misunderstanding of the effects of this technology on children, particularly on their intellectual and emotional development.

It was almost three decades after television's inception before any substantial research efforts were made in the field of children and television. The research came "after-the-fact", at a time when people were concerned that children were being manipulated by the medium. The television industry had already charted its course, and the question was how could it be changed.

Research and development in the field of microcomputers and children must take advantage of the infancy stage of the field.

Standards have not yet been set. Unlike what has occured in the television-children domain, policy decisions regarding the use of microcomputers in schools can still be made as a result of investigation into this area. Research and policy can progress simultaneously and would be a positive service to education.

In the United States, microcomputer use is already seen as "scattered, random among schools, districts, and states, and unincorporated into long range plans" (Dickerson & Pritchard, p. 7). In a 1974 survey, 26% of all U.S. schools used computers for instructional purposes (Molnar, 1981). It had been predicted that by 1982 the figure would jump to 70% (Diem, 1981), and that the percentage would increase steadily throughout the decade. This appears to be a universal phenomenon. It prompts concern that education (research and practice) must seize its chance now to get in on the ground floor of this period of development of sophisticated technology in the schools. Bourgue (1982) predicts that "computer literacy tomorrow will be almost as important as reading skills are today" (p. 47).

In the following sections I will consider, first, creative problem-solving in general; second, computer programming and problem-solving; and third, the interface between humans and technology. Finally, I will discuss today's urgent need for computer literacy.

Creative Problem Solving

One of the main goals of education is to take theories of learning, cognition, and development, and to implement them into curriculum designs that allow children to develop higher order mental skills and strategies (Winn, 1981). The interaction between teaching and learning is supposed to be a creative process between the teacher (be it a person or a machine) and the student (Rainsberry, 1975).

Theories of learning, instructional design, and psychological development have not only contributed to our understanding of the information processes involved in the learning environment, but have also assisted in creating more optimal conditions in which learning and creative problem-solving can occur. Whichever school of thought one wishes to borrow from (be it Bloom, Polya, Bruner, or Gagné) the higher order skills involved in problem-solving generally include such processes as planning, abstraction, generalization, and understanding. Piagetians believe that children ought to develop these skills in an "active" way. Piaget investigated the acquisition of knowledge and generally concluded that to develop cognitively, children must internalize the structure of events they come into contact with. The internal representation characteristics of any given child depends upon the stage of development and the already existing schemata or mental operations within the child's own cognitive structure. An essential point made by Piaget is that there must be constant give and take between external stimuli and the child's own conceptions of the world — the child is not seen as a passive learner in the Piaget learning context. The environment is set up to encourage cognitive development and formal reasoning skills.

Vygotsky (in Levin & Kareev, 1980) speaks of a similar concept — the idea of 'proximal development'. Essentially, Vygotsky reinforces Piaget's thoughts on the importance of creating learning environments that allow for interplay between external and internal processes. It is the task of the psycho-educational researcher and instructional designer to investigate the nature of these processes and to attempt to create suitable learning environments. These will be environments where maximal learning can take place and where children themselves not only have opportunities to "represent what they have come to know" (Eisner, 1982, p. ii), but can also begin to understand their own thought processes. This latter self-regulatory skill (metacognition) is developmental in nature and is seen as a positive feature of cognitive skill transfer (Flavell, 1976).

The above is a cognitive approach to teaching and learning. Its main premise is the "support of the *internal* processes of learning" (Lipsitz, 1982, p. 11). This support, it must be stressed, is given within a context of active involvement on the part of the learner. It promotes strong intrinsic motivation and the development of such creative thinking skills as discovery, formulation of problems and generation of ideas, and evaluation.

Eisner (1982) states that what we seek in education is "to liberate rather than to control" (p. 56). He suggests that we must introduce children to a variety of forms of representation in order to develop in them the necessary skills of literacy. Children must, he says, be allowed to manipulate and have opportunities to use various media of expression in order to develop cognitively and inventively.

Programming and Problem-Solving

The computer can play an extremely valuable role in the encouragement of a child's cognitive development. It provides, for example, the opportunity to formulate ideas, to generate solutions to problems and to evaluate these solutions. Because of the nature of the machine, these processes promote formal reasoning.

As educators recognize the need to go beyond drill and practice exercises with the computer, emphasis is being placed on teaching the skills of programming to children. Doing so accomplishes the goal of making the computer the intellectual tool of the child rather than vice versa.

With the advent of inexpensive and extremely portable microcomputers, the possibility of teaching programming skills to children of all ages is readily available. A truly 'interactive' experience between computer and child allows the child to write simple programs, invent, and problem solve. Such creative interaction leads to both the support and development of information-processing capabilities (*not necessarily their acceleration!*) and in turn to researchers' better understanding of the thought processes of children under such teaching-learning circumstances.

Research possibilities in the cognitive domain are numerous. However, examination of the various ways of putting the microcomputers into the hands of children must be done first. Research and development is badly needed to refine and develop programming languages that children can learn to use. Ershov (1981) stressed this latter point in his keynote address to the World Conference on Computers in Education.

Kahn (1973) presents a model for interactive computer programming as problem-solving. According to Kahn, programming consists of two main processes, 'restructuring' and 'coding'. Essentially, interactive programming becomes a form of communication between individual and machine. The individual develops thinking skills through planning and solving problems. These tasks involve flowcharting, sequencing, and debugging skills which when exercised support the development of the individual's information-processing capabilities. Kahn supports teaching children programming because the nature of the system "makes the process of thinking concrete and visible to the child" (p. 8). This kind of active, 'hands on' approach to teaching young children is certainly consistent with Piagetian thought.

Programming a computer supports many of the intellectual and motivational components which make learning a positive developmental experience for the child. It involves many problem-solving techniques that not too many other tasks can offer children, and it does so in an exciting way. The advent of microcomputers has allowed educators to put the tools of creative experimentation into the hands of children. But we must go beyond prepared computer programs for children and teach *them* to author their own. As Critchfield (1979) says, "to deliver instruction via computer programs, but not teach students to program themselves would be like reading books to students, but never letting them learn to read for themselves" (p. 25).

Seymour Papert and his research group at M.I.T.'s Artificial Intelligence Laboratory have demonstrated that one can borrow from the schools of psychology, epistemology, education, and computer science to develop in children the cognitive skills of computational logic and other problem-solving strategies. His research team has developed a programming language called LOGO which even very young children have learned to manipulate. The work of the LOGO group is documented in numerous 'LOGO Memos' which support the general aim of promoting problem-solving skills through programming (Papert, 1971a, 1971b, 1971c, 1973, 1976; Papert & Solomon, 1971; Solomon, 1975; Solomon & Papert, 1976; Goldstein & Miller, 1976). "Two major themes (highlight the LOGO work) — that children can learn to use computers in a masterful way, and that learning to use computers can change the way they learn everything else . . ." (Papert, 1980, p. 8). Watt (1982) describes four projects which are in the process of examining the use of LOGO to teach cognitive skills such as problem-solving. The "Lamplighter Project" is particularly interesting. It has demonstrated that even first and second graders can learn to write simple programs. As Watt reports, and this may be as important a result of the experience as learning to program, "competition, cooperation, communication, problem-solving, programming, geometry, and artistry all happened at once" (p. 132).

Most of the research on LOGO, children, and microcomputers appears to be still in the developing stage. There is definitely room for more research of this kind. Not only is there proof that even young children have the ability to learn from the microcomputer, but it is also clear that we can learn about children's learning processes by having them "experiment" with the technology.

The Interface Between Humans and Technology

What has been discovered from the schools of cognitive-developmental psychology and education (in terms of theories of teaching and learning) and what has evolved as a result of research in certain laboratories of computer science (particularly in the area of artificial intelligence) both have important contributions to make in terms of our understanding of the development of literacy and the cognitive skills that allow individuals to make sense of stimuli around them. There are definite similarities between facets of data processing (including searching, sorting, deleting, and summarizing) and the human processes of problem-solving. Children who are involved in problem-solving tasks not only develop better understanding of their own mental abilities, but also develop insight into the functioning of a technology whose 'magic' they can learn to control. This is a circular process. It recognizes that increased skill with the computer will develop the cognitive structures of those children who come into contact with the technology. As Seymour Papert (1980) states, "computer presence could contribute to mental processes . . . influencing how people think" (p. 4). Papert continues by saying that the idea is that of giving children "objects to think with" (p. 11) — cognitive tools. This is the key to developing a truly creative and stimulating learning situation. Not only are children able to practice their problem-solving skills, but the computer makes them aware of their own thought processes through immediate feedback (Kahn, 1973).

A truly 'interactive' encounter with the computer provides the type of active learning environment of the Piagetian school. Here the child proceeds at his/her own pace and level of development, calling upon already-existing mental operations and developing new ones, building analytical skills, and 'learning about lear-

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ning'. Computer logic and human logic do not necessarily become one, but they complement each other as the child grows and learns.

The Need for Computer Literacy

There is rarely an article in the field of computers and education that does not stress the need to supply children (and ultimately society) with knowledge about computers. The advent of microcomputers has made this an even more urgent need. "The literature predicts that computer literacy will be the next crisis in education . . . the potential for computer illiteracy poses a challenge to the educational community which must *not* be ignored" (Dickerson & Pritchard, 1981, p. 7).

Molnar (1981) defines computer literacy as "what a person needs to know and do with computers in order to function competently in our society" (p. 27). It is the 'do' that is the all-too-often forgotten element of computer literacy — a function that is strongly stressed in this paper. Watt (undated) sees one category of computer literacy as being that of learning to program — a skill of problem-solving, analyzing, and predicting outcomes.

The main issue here is that it is not sufficient to teach children *about* microcomputers; what the computer can do for them must transfer into what they can do with the computer (keeping in mind that the essential element is cognitive skill building). Computers may be a powerful 'tool' for learning, but they can also be a very effective medium of expression. When the latter goal is reached (through whatever instructional method one chooses to employ), the control is no longer in the hands of the technology, but rather in the hands of the child. Learning and thinking become active, creative processes controlled by the learner!

Designing such environments and taking into account cognitive-developmental and other individual differences is a worthy goal for educators in the field of microcomputers and education. If children are denied the opportunities to create, to program, to 'represent' through such a form of representation as a microcomputer, then they are being denied the chance to develop creatively and education will be losing an opportunity to use one of the most sophisticated media of expressions available. "Educators must take the lead in showing how this can be done by exploring the many possible ways in which computer use can enhance subject matter learning and student creativity" (Critchfield, 1979, p. 18).

Conclusion

There is strong theoretical support for investigating further the interaction between computers and children. As emphasized in the introduction, researchers must seize the opportunity now. Microcomputers are everywhere, and it is our responsibility to set the stage for their sound use in the school system. We can only do so through research studies. There is now a real dearth of work in the microcomputer and children area. There are many questions to be answered: What can these sophisticated tools offer children and in turn what can young learners bring to this new mode of representation? At what age can microcomputers be introduced to children? At what age can children successfully learn simple programming techniques? Solving such research questions while keeping in mind the notions of learning, development, and instructional design as previously outlined, will in turn serve both education and society in general. In his report to the National Institute of Education, Hall (1981) called for more research into what children can do with computers. Such research is necessary in order to establish policy strategy. This need for research has been expressed internationally as countries recognize the impact of microcomputers on society and the need to establish guidelines for their introduction and use in schools.

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