RUN: Computer Education

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Preface

Teachers, parents, and even students are bringing personal computers into the classroom in an impressively growing grass roots movement. The benefits of having microcomputers in schools are obvious to anyone who has witnessed the enthusiastic response of students using them. A critical need exists, however, for information aimed at teachers of all grade levels and subject areas because so many teachers are inadequately prepared to understand the new technology fully. To fill this void we have selected and categorized pertinent articles about the use of microcomputers in precollege education. These articles reflect a sense of high excitement and optimism in the academic community regarding instructional computer use.

This book is designed as a text or reference book for educational colleges or school districts offering computer literacy to preservice or inservice elementary or secondary teachers; it can easily serve other audiences as well. The wide range of topics makes it a valuable starting point for anyone interested in exploring the rapidly expanding world of computing. Educators of any group from kindergarten to university level will find each chapter professionally rewarding and instructive. Computing and noncomputing teachers, professors, student teachers, and school administrators can all benefit from this text. In addition, the casual reader will find most chapters offer a wealth of interesting, fundamental information regarding educational computer use. The teacher's manual offers other sources of information to those who wish to pursue a particular theme, as well as many practical discussion topics and exercises intended to involve people in a teacher-training program.

The suggested activities are presented on two levels to take advantage of differences in teachers and teacher trainers. The "What's Your Opinion" section at the end of each chapter contains key points from the preceding articles. These statements can be used as the seeds for class or group discussions, homework assignments, summarizations, debates, and other uses as outlined in the teacher's manual.

The "Exercises," also found at the end of each chapter, provide topics for essay questions, assignments, projects, and similar activities requiring extra-curricula study or research by the student.

The articles are written by many of the leaders in instructional computing throughout the world. Names such as Papert, Bork, Taylor, Billings, Braun, Moursund, Poirot, Molnar, Jones, Luehrmann, Klassen, Watt, Dennis, and Chambers are very familiar to computer educators. These authors and others provide expert analyses of the major issues facing educators in this age of information. The diverse writing styles and opinions of the authors provide an excellent cross-section of the current, relevant literature.

We extend our sincere appreciation to Dr. R. Murray Thomas of the University of California, Santa Barbara, whose encouragement, support, and expertise were great aids to the fruition of this text. We thank the reviewers of the manuscript, whose thoughtful comments were also great aids: Cheryl A. Anderson, University of Texas; J. Richard Dennis, University of Illinois; Barbara Dubitsky, Bank Street College of Education; Dorothy H. Judd, Northern Illinois University; Jacqueline McMahon, University of Missouri; and Ted Sjoldsma, University of Iowa.

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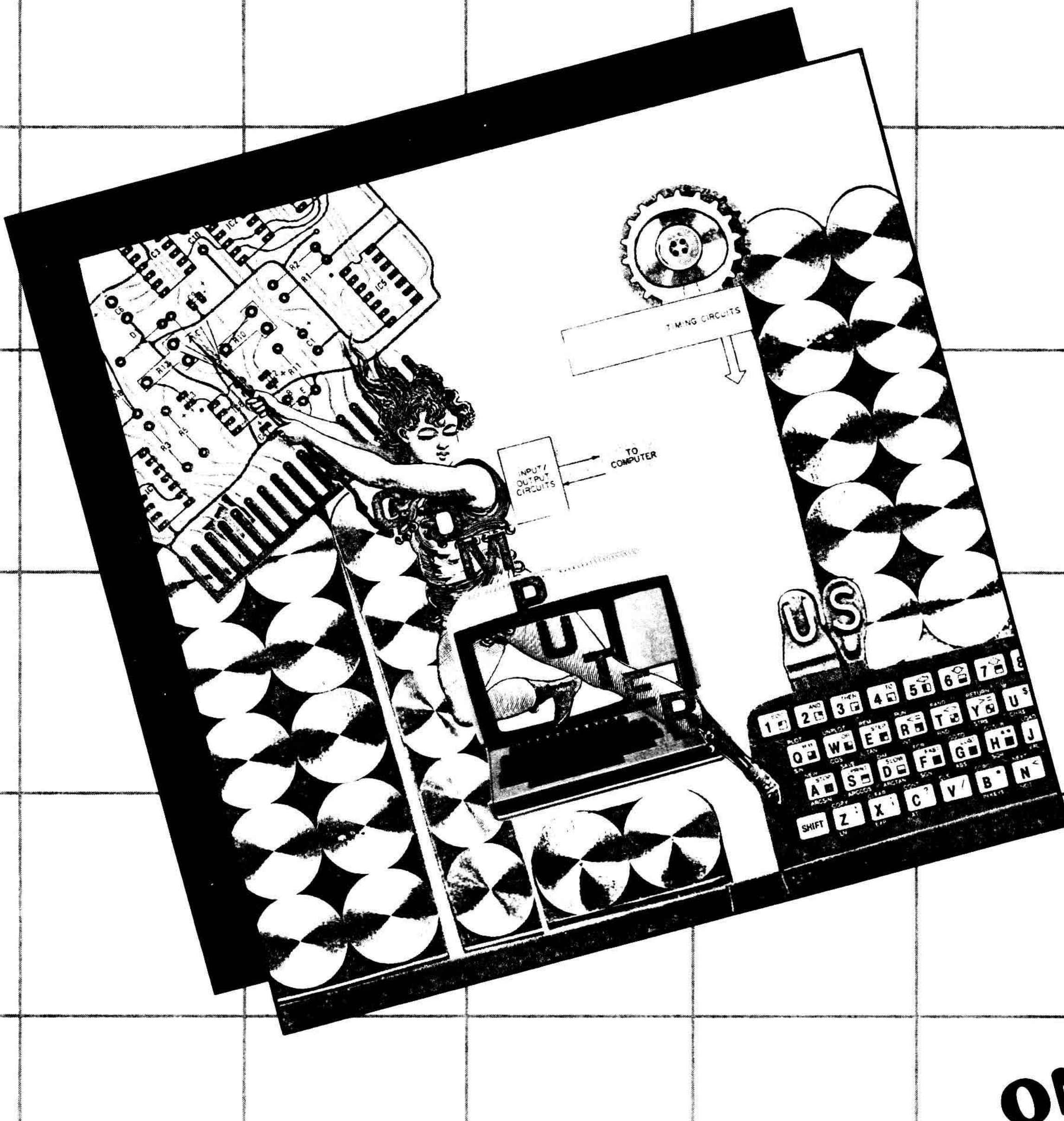

ONE

Teaching and Learning Theory

Examining the place of the microcomputer in the learning process, this chapter shows that educators are becoming increasingly aware of the machine's versatility, power, and potential for the classroom. The microcomputer offers a reason for analyzing and revising entire curricula as well as the impetus for devising totally new methods of instruction. Indeed, once introduced to microcomputers, teachers soon realize that their imagination is the only limiting factor in the creation of classroom applications.

With infec ious enthusiasm Seymour Papert describes his application of Piagetian theory to the teaching of math and of programming concepts to young children; his successes with the LOGO environment are exciting. He demonstrates that children can learn about computing *by* computing. Drawing an analogy between the QWERTY typewriter keyboard and the popular BASIC language, he suggests that both fail to resolve their respective problems adequately and forecasts their long-range detrimental effects. Darlene Crawford offers both an intelligent assessment of future needs and suggestions for program implementation. She shows how the microcomputer can be used to solve the problems of the barriers between home and school as well as between teachers and computerization. John D'Angelo notes that the microprocessor offers a method of rethinking and restructuring current educational delivery systems. As George Miller suggests, however, though the computer culture may be inevitable, human nature will endure. Examining the value of the computer versus that of the human teacher, Miller concludes that each has its own particular role to play.

Computers and Computer Cultures

Seymour Papert

In most contemporary educational situations where children come into contact with computers the computer is used to put children through their paces, to provide exercises of an appropriate level of difficulty, to provide feedback, and to dispense information. The computer programming the child. In the LOGO environment the relationship is reversed: The child is in control: The child programs the computer. And in teaching the computer how to think, children embark on an exploration about how they themselves think. Thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults.

After five years of study with Jean Piaget in Geneva, I came away impressed by his way of looking at children as the active builders of their own intellectual structures. To say that intellectual structures are built by the learner rather than taught by a teacher does not mean that they are built from nothing. Like other builders, children appropriate to their own use materials they find about them, most saliently the models and metaphors suggested by the surrounding culture.

Piaget writes about the order in which the child develops different intellectual abilities. I give more weight than he does to the influence of the materials a certain culture provides in determining that order. For example, our culture is very rich in materials useful for the child's construction of certain components of numerical and logical thinking. Children learn to count; they learn that the result of counting is independent of order and special arrangement; they extend this "conservation" to thinking about the properties of liquids as they are poured and of solids which change their shape. Children develop these components of thinking preconsciously and "spontaneously," that is to say without deliberate teaching. Other components of knowledge, such as the skills involved in doing permutations and combinations, develop more slowly, or do not develop at all without formal schooling.

The computer presence might have more fundamental effects than did other new technologies, including television and even printing. The metaphor of computer as a mathematics speaking entity puts the learner in a qualitatively new kind of relationship to an important domain of knowledge. Even the best of educational television is limited to offering quantitative improvements in the kinds of learning that existed without it. **Sesame Street** might offer better and more engaging explanations than a child can get from some parents or nursery school teachers, but the child is still in the business of listening to explanations. By contrast, when a child learns to program, the process of learning is transformed. It becomes more active and self directed. The knowledge is acquired for a recognizable personal purpose. The child does something with it. The new knowledge is a source of power and is experienced as such from the moment it begins to form in the child's mind.

I have spoken of mathematics being learned in a new way. But much more is affected than mathematics. Piaget distinguishes between "concrete" thinking and "formal" thinking. Concrete thinking is already well on its way by the time the child enters first grade at age 6 and is consolidated in the following several years. Formal thinking does not develop until the child is almost 12, give or take a year or two, and some researchers have even suggested that many people never achieve fully formal thinking. I do not fully accept Piaget's distinction, but I am sure that it is close enough to reality to help us make sense of the idea that the consequences for intellectual development of one innovation could be qualitatively greater than the cumulative quantitative effects of a thousand others. My conjecture is that the computer can concretize (and personalize) the formal. Seen in this light, it is not just another powerful educational tool. It is unique in providing us with the means for addressing what Piaget and many others see as the obstacle which is overcome in the passage from child to adult thinking. I believe that it can allow us to shift the boundary separating concrete and formal. Knowledge that was accessible only through formal processes can now be approached concretely. And the real magic comes from the fact that this knowledge includes those elements one needs to become a formal thinker.

This description of the role of the computer is rather abstract. I shall concretize it by looking at the effect of working with computers on two kinds of thinking Piaget associates with the formal stage of intellectual development: combinatorial thinking, where one has to reason in terms of the set of all possible states of a system, and self referential thinking about thinking itself.

In a typical experiment in combinatorial thinking, children are asked to form all the possible combinations (or "families") of beads of assorted colors. It really is quite remarkable that most children are unable to do this systematically and accurately until they are in the fifth or sixth grades. Why should this be? Why does the task seem to be so much more difficult than the intellectual feats accomplished by seven and eight year old children? Is its logical structure essentially more complex? Can it possibly require a neurological mechanism that does not mature until the approach of puberty? I think that a more likely explanation is provided by looking at the nature of the culture. The task of making the families of beads can be looked at as constructing and executing a program, a very common sort of program, in which two loops are nested: Fix a first color and run through all possible second colors, then repeat until all possible first colors have been run through. For someone who is thoroughly used to computers and programming there is nothing "formal" or abstract about this task. For a child in a computer culture it would be as concrete as matching up knives and forks at the dinner table. Even the common "bug" of including some families twice (for example, red-blue and blue-red) would be well known. Our culture is rich in pairs, couples, and one to one correspondences of all sorts, and it is rich in language for talking about such things. This richness provides both the incentive and a supply of models and tools for children to build ways to think about such issues as whether three large pieces of candy are more or less than four smaller pieces. For such problems our children acquire an excellent intuitive sense of quantity. But our culture is relatively poor in models of systematic procedures. Until recently there was not even a name in popular language for programming, let alone for the ideas needed to do so successfully. There is no word for "nested loops" and no word for the double counting bug. Indeed, there are no words for the powerful ideas computerists refer to as "bug" and "debugging."

Without the incentive or the materials to build powerful, concrete ways to think about problems involving systematicity, children are forced to approach such problems in a groping, abstract fashion. Thus cultural factors can explain the difference in age at which children build their intuitive knowledge of quantity and of systematicity.

While still working in Geneva I had become sensitive to the way in which materials from the then very young computer cultures were allowing psychologists to develop new ways to think about thinking. In fact, my entry into the world of computers was motivated largely by the idea that children could also benefit, perhaps even more than the psychologist, from the way in which computer models seemed to be able to give concrete form to areas of knowledge that had previously appeared so intangible and abstract.

I began to see how children who had learned to program computers could use very concrete computer models to think about thinking and to learn about learning and in doing so, enhance their powers as psychologists and as epistemologists. For example, many children are held back in their learning because they have a model of learning in which you have either "got it" or "got it wrong." But when you learn to program a computer you almost never get it right the first time. Learning to be a master programmer is learning to become highly skilled at isolating and correcting "bugs," the parts that keep the program from working. The question to ask about the program is not whether it is right or wrong, but if it is fixable. If this way of looking at intellectual products were generalized to how the larger culture thinks about knowledge and its acquisition, we might all be less intimidated by our fears of "being wrong." This potential influence of the computer on changing our notion of a black and white version of our successes and failures is an example of using the computer as an "object to think with." It is obviously not necessary to work with computers in order to acquire good strategies for learning. Surely "debugging" strategies were developed by successful learners long before computers existed. But thinking about learning by analogy with developing a program is a powerful and accessible way to get started on becoming more articulate about one's debugging strategies and more deliberate about improving them.

My discussion of a computer culture and its impact on thinking presupposes a massive penetration of powerful computers into people's lives. That this will happen there can be no doubt. The calculator, the electronic game, and the digital watch were brought to us by a technical revolution that rapidly lowered prices for electronics in a period when all others were rising with inflation. That same technological revolution, brought about by the integrated circuit, is now bringing us the personal computer.

There really is no disagreement among experts that the cost of computers will fall to a level where they will enter everyday life in vast numbers. Some will be there as computers proper, that is to say, programmable machines. Others might appear as games of ever increasing complexity and in automated supermarkets where the shelves, maybe even the cans, will talk. There is no doubt that the material surface of life will become very different for everyone, perhaps most of all for children. But there has been a significant difference of opinion about the effects this computer presence will produce. I would distinguish my thinking from two trends of thinking which I refer to here as the "skeptical" and the "critical."

Skeptics do not expect the computer presence to make much difference in how people learn and think. I have formulated a number of possible explanations for why they think as they do. In some cases I think the skeptics might conceive of education and the effect of computers on it too narrowly. Instead of considering general cultural effects, they focus attention on the use of the computer as a device for programmed instruction. Skeptics then conclude that while the computer might produce some improvements in school learning, it is not likely to lead to fundamental change. In a sense, too, I think the skeptical view derives from a failure to appreciate just how much Piagetian learning takes place as a child grows up. If a person conceives of children's intellectual development (or for that matter, moral or social development) as deriving chiefly from deliberate teaching, then such a person would be likely to underestimate the potential effect that a massive presence of computers and other interactive objects might have on children.

The critics, on the other hand, do think that the computer presence will make a difference and are apprehensive. For example, they fear that more communication via computers might lead to less human association and result in social fragmentation. As knowing how to use a computer becomes increasingly necessary to effective social and economic participation, the position of the underprivileged could worsen, and the computer could exacerbate existing class distinctions. As to the political effect computers will have, the critics' concerns resonate with Orwellian images of a 1984 where home computers will form part of a complex system of surveillance and thought control. Critics also draw attention to potential mental health hazards of computer penetration. Some of these hazards are magnified forms of problems already worrying many observers of contemporary life; others are problems of an essentially new kind. A typical example of the former kind is that our grave ignorance of the psychological impact of television becomes even more serious when we contemplate an epoch of super TV. The holding power and psychological impact of the television show could be increased by varying the content to suit the tastes of each individual viewer, and by the show becoming interactive, drawing the viewer into the action. Critics already cite cases of students spending sleepless nights riveted to the computer terminal, coming to neglect both studies and social contact.

In the category of new problems, critics have pointed to the influence of the allegedly mechanized thought processes on how people think. Marshall MacLuhan's dictum that "the medium is the message" might apply here: If the medium is an interactive system that takes in words and speaks back like a person, it is easy to get the message that machines are like people and that people are like machines. What this might do to the development of values and self image in growing children is hard to assess. But it is not hard to see reasons for worry.

Despite these concerns I am essentially optimistic —some might say utopian—about the effects of computers on society. I do not dismiss the arguments of the critics. On the contrary, I too see the computer presence as a potent influence on the human mind. I am very much aware of the holding power of an interactive computer and of how taking the computer as a model can influence the way we think about ourselves. In fact the work on LOGO to which I have devoted much of the past ten years consists precisely of developing such forces in positive directions. For example, the critic is horrified at the thought of a child hypnotically held by a futuristic, computerized super pinball machine. In the LOGO work we have invented versions of such machines in which powerful ideas from physics or mathematics or linguistics are imbedded in such a way that permits the player to learn them in a natural fashion, analogous to how a child learns to speak. The computer's "holding power," so feared by critics, becomes a useful educational tool. Or take another, more profound example. The critic is afraid that children will adopt the computer as model and eventually come to "think mechanically" themselves. Following the opposite tack, I have invented ways to take educational advantage of the opportunities to master the art of *deliberately* thinking like a computer, according, for example, to the stereotype of a computer program that proceeds in a step-by-step, literal, mechanical fashion. There are situations where this style of thinking is appropriate and useful. Some children's difficulties in learning formal subjects such as grammar or mathematics derive from their inability to see the point of such a style.

A second educational advantage is indirect but ultimately more important. By deliberately learning to imitate mechanical thinking, the learner becomes able to articulate what mechanical thinking is and what it is not. The exercise can lead to greater confidence about the ability to choose a cognitive style that suits the problem. Analysis of "mechanical thinking" and how it is different from other kinds and practice with problem analysis can result in a new degree of intellectual sophistication. By providing a very concrete, down to earth model of a particular style of thinking, work with the computer can make it easier to understand that there is such a thing as a "style of thinking." And giving children the opportunity to choose one style or another provides an opportunity to develop the skill necessary to choose between styles. Thus instead of inducing mechanical thinking, contact with computers could turn out to be the best conceivable antidote to it. And for me what is most important in this is that through these experiences these children would be serving their apprenticeship as epistemologists, that is to say learning to think articulately about thinking.

The intellectual environments offered to children by today's cultures are poor in opportunities to bring their thinking about thinking into the open, to learn to talk about it and test their ideas by externalizing them. Access to computers can dramatically change this situation. Even the simplest Turtle work can open new opportunities for sharpening one's thinking about thinking: Programming the Turtle begins by making one reflect on how one does oneself what one would like the Turtle to do. Thus teaching the Turtle to act or to "think" can lead one to reflect on one's own actions and thinking. And as children move on, they program the computer to make more complex decisions and find themselves engaged in reflecting on more complex aspects of their own thinking.

In short, while the critic and I share the belief that working with computers can have a powerful influence on how people think, I have turned my attention to exploring how this influence could be turned in positive directions.

The central open questions about the effect of computers on children in the 1980s are these: Which people will be attracted to the world of computers, what talents will they bring, and what tastes and ideologies will they impose on the growing computer culture? I have observed children in LOGO environments engaged in self-referential discussions about their own thinking. This could happen because the LOGO language and the Turtle were designed by people who enjoy such discussion and worked hard to design a medium that would encourage it. Other designers of computer systems have different tastes and different ideas about what kinds of activities are suitable for children. Which design will prevail, and in what subculture, will not be decided by a simple bureaucratic decision made, for example, in a government Department of Education or by a committee of experts. Trends in computer style will emerge from a complex web of decisions by foundations with resources to support one or another design, by corporations who may see a market, by schools, by individuals who decide to make their career in the new field of activity, and by children who will have their own say in what they pick up and what they make of it. People often ask whether in the future children will program computers or become absorbed in pre-programmed activities. The answer must be that some children will do the one, some the other, some both, and some neither. But which children, and most importantly, which social classes of children, will fall into each category will be influenced by the kind of computer activities and the kind of environments created around them.

As an example, we consider an activity which may not occur to most people when they think of computers and children: the use of the computer as a writing instrument. For me, writing means making a rough draft and refining it over a considerable period of time. My image of myself as a writer includes the expectation of an "unacceptable" first draft that will develop with successive editing into presentable form. But I would not be able to afford this image if I were a third grader. The physical act of writing would be slow and laborious. I would have no secretary. For most children rewriting a text is so laborious that the first draft is the final copy, and the skill of rereading with a critical eye is never developed. This changes dramatically when children have access to computers capable of manipulating text. The first draft is composed at the keyboard. Corrections are made easily. The current copy is always neat and tidy. I have seen children move from total rejection of writing to an intense involvement (accompanied by rapid improvement of quality) within a few weeks of beginning to write with a computer. Even more dramatic changes are seen when the child has physical handicaps that make writing by hand more than usually difficult or even impossible.

This use of computers is rapidly being adopted wherever adults write for a living. Most newspapers now provide their staff with "word processing" computer systems. Many writers who work at home are acquiring their own computers, and the computer terminal is steadily displacing the typewriter as the secretary's basic tool. The image of children using the computer as a writing instrument is a particularly good example of my thesis that what is good for professionals is good for children. But this image of how the computer might contribute to children's mastery of language is dramatically opposed to the one that is taking root in most elementary schools. There the computer is seen as a teaching instrument. It gives children practice in distinguishing between verbs and nouns, in spelling, and in answering multiple choice questions about the meaning of pieces of text. As I see it, this difference is not a matter of a small and technical choice between two teaching strategies. It reflects a fundamental difference in educational philosophies. More to the point, it reflects a difference in view on the nature of childhood. I believe that the computer as writing instrument offers children an opportunity to become more like adults, indeed like advanced professionals, in their relationship to their intellectual products and to themselves. In doing so, it comes into head-on collision with the many aspects of school whose effect, if not whose intention, is to "infantilize" the child.

Word processors *can* make a child's experience of writing more like that of a real writer. But this can be undermined if the adults surrounding the child fail to appreciate what it is like to be a writer. For example, it is only too easy to imagine adults, including teachers, expressing the view that editing and re-editing a text is a waste of time ("Why don't you get on to something new?" or "You aren't making it any better, why don't you fix your spelling?").

As with writing, so with music making, games of skill, complex graphics, whatever: The computer is not a culture unto itself but it can serve to advance very different cultural and philosophical outlooks. For example, one could think of the Turtle as a device to teach elements of the traditional curriculum, such as notions of angle, shape, and coordinate systems. And in fact, most teachers who consult me about its use are trying to use it in this way. Of course the Turtle can help in the teaching of traditional curriculum, but I have thought of it as a vehicle for Piagetian learning, which to me is learning without curriculum.

There are those who think about creating a "Piagetian curriculum" or "Piagetian teaching methods." But to my mind these phrases and the activities they represent are contradictions in terms. I see