15. Personal Computing and Its Impact on Education

[Note: This paper was taken from a tape recording of Dr. Papert's talk; it was transcribed by Roxanne Berridge, paraphrased by Ted Sjoerdsma, and edited by Anne Adair.]

I would like to begin by describing a fantasy that I was making a few months ago with the director of the Aspen Ski School.

If you know anything about skiing, you know that sometimes when the snow is just right, it is very easy to come down the slope. You can do the turns, with the snow itself practically ushering you through the right motions. Everything is so right that you think you are the greatest skier that ever walked. Later, of course, you learn otherwise.

My fantasy is based on that idea. Could you engineer a mountain with a dynamically variable slope determined by the expertise of the skier? A beginner on top of the mountain would start a very gentle slope. Off he goes. As he acquires enough confidence to stay up on his skis the characteristics of the slope change. This continues until he gets to the bottom of the mountain and he is a skier. So he learns because his environment is designed in such a way that it changes with his needs.

I don't know whether you could make such a mountain or not. The ski director and I talked a long time about what is involved in skiing and human beings, and we couldn't decide. I doubt that you could make a mountain so that one time down would produce a skier. But I do know that the amount of time that it takes to learn to be an expert skier has been divided by 20 in the last 20 years. The level of skiing ability which everyone expects to reach (and most do) in one season of skiing is a level much higher than most people in the

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olden days ever expected to reach even if they went skiing every vacation, every winter, for all their lives.

This is all quite interesting, but how does it relate to education? And more particularly, to computers in education? Is skiing a good model to study with implications for education? Maybe it is time for those who are trying to reform the educational process to start looking at the success stories like the improvement in skiing education. Where the learning is much better than it used to be, one should go see what happened and attempt to transcribe that to the formal education of children.

One of the themes I would like you to keep in mind during this talk is: if you are interested in how learning happens, you should start by looking at success stories. It is amazing that if you look at the articles in the journals of education and educational psychology, you'll find that they are all about failures. The whole subject is based on how badly people learn in the environment (schools) in which they *should* learn very well. We should rather think about success stories of good learning.

I would also like us to catch the vision of aspiring to something bigger and better, of some kind of change or improvement which would make things a little better in our schools. It doesn't turn me on to think that we teach computing in schools because it is a basic skill and something that everyone ought to know. What does turn me on is the hope that the computer in some sense might be the magic mountain. What I am really interested in is not teaching about computers (however important that might be), but rather determining whether knowing about computers can really deeply change everything else. So let me tell you a story or two—little anecdotes about learning with computers that did deeply change everything else for some people.

Before the stories I should supply the background. For the past ten years we have been involved in a project at MIT which is designed to try to bring kids and computers together. Philosophically the background is this: In 1967 I first got involved with kids and computers. Watching one of the first projects — high school kids trying to learn to program using a Model 33 terminal and a terrible language—it was obvious that it was great for some kids. But it was even more obvious that it wasn't the way to go. So we decided to sit back in our ivory towers and think about what could be done with the computers that *might* exist ten years ahead. (Ten years ahead is about now.)

We did decide a few things. Computers should be personal computers. Computers should be action-oriented (draw pictures, make noises, make objects move around). And there should be a programming language or a programming system that didn't just happen to be lying around, but was made for the purpose.

We set out to make a collection of all the nice features of all the known programming languages, so that we could put together a language that would allow a kid to really communicate with a computer. What we were trying to do was to find out what a first grader (or a kid of any age) could do with a computer. Out of our many years of experience, one fact became very clear—*kids of all ages can learn to program.*

In case you are amazed at that statement, consider programming as *talking to a computer in its language*. Kids have no trouble learning to talk to people. Even two-year-olds are already talking to people with more proficiency than the kids in a high school BASIC class are learning to talk to the computer, or the kids in a high school French class are learning to speak French. Surely, there must be a way to get the kids to learn to talk to computers the way they learn to talk to people. Why should it be harder to talk "computer" (as kids say) than it is to talk English? (This becomes a guiding theme.) We decided that one reason why it seems harder is that there are no good things to talk *about*. So we put graphics on the computer, which certainly is something to talk about. Kids can now make pictures and do things with computer pictures that they can't do with pencil and paper pictures. They can get precisions, get repeatability, depict motion, change color, and do all sorts of other things that can't be done with pencil and paper.

We suddenly came into quite a number of dimensions of the educational enterprise, or what it is to learn. For example, there is something that is called social resonance. It became very clear that just because kids spent a lot of time watching television in the home, making a picture on the television screen gives them a special kind of charge. A kid who is taking over the television screen so that he can make pictures himself is moving into the space age. And something of that drive makes all of us want to buy little calculators (that we could perfectly well do without) because we would each like to have, as our very own, a piece of that space age technology. This carries over to our kids, again a sort of social resonance. The kid feels like he is doing something meaningful, like those guys he sees in the space center controlling a moon rocket. The computer, just because it is high technology, provides a certain bridge between the learner and the world.

I would like to have you examine an even more important bridge, the one between the learner and himself, between what is being learned and what is deep down inside him. I will try to get you to sense what I mean, even though I cannot fully explain it.

We were all sort of led bit-by-bit into a view of education that is more Freudian than Piagetian. Jean Piaget is a psychologist and an epistemologist. He thinks of mathematics in a very logical way, rigorous and precise. And I think that he is right in a lot of his insights. What I am trying to say is that there is a model of mathematics which doesn't have much to do with my feelings. The general view of mathematics in our culture is that it is something separate from our bodies, cold and discorporate.

Let me show you a different view of mathematics and an example of what it is like. Let's go back to those children learning to make pictures on the television screen. How do you go about making a picture on the television screen? The child is creating it, controlling it, intellectually interacting with it; he is not just pushing buttons and flashing things on the screen as if by magic. Thus we became involved in the enterprise of how to think of geometry. After a lot of false starts, we came up with what I think is the absolutely right way to think about geometry. This is the concept of "turtle." "Turtle" is a differential equation—differential geometry in computational terms.

Let me explain how we present it to a child, and then maybe you won't worry about it being differential geometry. I believe that what we are talking about has a certain great importance, not because it is capturing an idea that we invented, but because it is capturing ideas of science and bringing it into a new view—and the new view is possible only because of the computer's presence. It is this creation of new visions of old things that is one of the magics of the computer.

We bring in the child and introduce him to a little cybernetic animal called a "turtle". The turtle is controlled by the computer and the computer is controlled by the child. The turtle is positioned somewhere and is looking in some direction. This is his state. To change his state, there are two different change operations: forward and turning. Forward causes him to change his position without changing the direction that he is looking. The turning operation allows him to change his position without changing the direction that he is looking. The turning operation allows him to turn to the right or the left without changing his position. These two operations (coordinates) can change the two components of the state independently and thus the child can get the turtle to perform any maneuver. If the child equips the turtle with a pen, then sets it on paper, the turtle could draw things. (Alternately, one could introduce the child to the turtle on a display screen, which could obey the same commands, but now draws pictures with the speed of light.) Understanding the geometric concept of the state of the turtle, with its two kinds of change operations, gives one a kind of mathematical knowledge which provides power to do things.

However, I don't want to emphasize that aspect, but rather a kind of learning that I call "body syntonic learning." Let me introduce this with an example. Imagine a child who has learned to drive the turtle; he knows how to say forward and how many units; he knows how to turn it and how many degrees of turn. By and large the child has been drawing straight line figures. One day the child asks, "How does it draw a circle?" We ask the child to figure this out for himself. We suggest that the child pretend that he is the turtle and walk in a circle and try to describe his movements in turtle language.

This is where we connect the geometry to the child. The turtle is especially suited to serve as what has been labeled a "transitional object." The child comes along knowing a lot about "body geometry." He knows how to walk around in space. He has a lot of geometric knowledge, but it's inside and he can't verbalize it. On the other hand, there is this abstract thing called mathematics which you want him to learn. And in between is the turtle—a mathematical object, but enough like a person for him to identify with and to transfer his knowledge of himself to. Because the turtle moves like he does, the child can apply the same description and sort of talk to it through the computer.

So we have seen two ways in which the learning of mathematics is different from the traditional. One way is social resonance. The other way is resonance with deep structures inside the person. In fact, this is where Freud and Piaget come together.

Let's return to the circle. When the child walks in a circle, he goes forward a bit and right a bit, forward a bit and right a bit, repeating this until he returns to his starting point. So, too, when he tells the turtle what to do: forward one, right one, repeated as often as necessary until it results in a circle, at least from a point of view that defines a circle as a curve of constant curvature. (You see that the curvature of a curve is how much you turn to how much you go forward.) If the child goes forward ten and right one, it would be a much flatter curve, and would produce a much larger circle that would look like a polygon. He could make a spiral by gradually decreasing the curvature. It is a very impressive thing to make a spiral and then to get all sorts of crazy pictures by putting spirals on top of one another. Mastering this idea of curvature by thinking of curves in terms of generating little changes is an extremely powerful idea. It is perfectly graphicable by these small children, and also very usable. This last aspect is the third way that this mathematics is different from school mathematics—its social resonance, its resonance with one's own body, and *its usefulness*. It can be used right now to do something exciting.

Here you might say, is applied mathematics instead of pure mathematics. It is a curious thing that the way we teach mathematics in the elementary school is very very pure. Historically, that is a very funny thing. Historically, mankind first made mathematics a part of doing other things, like navigating, commerce, magic, religion, and all sorts of architecture. Only bit-by-bit did that beautiful thing called pure mathematics become abstracted out. I think this is a right model. And it is the model that Piaget teaches us, too, if we look carefully. The right way to learn mathematics is first learning it as a concrete applied thing that actually works in the world, and then gradually we get to pure mathematics.

So here is a model for a computer making a radical difference to the world. It is not just able to change how we teach the same algebra and the same equation in the same number of years. It can change the entire relationship to mathematics. And not only mathematics. I chose mathematics only because, in our society, mathematics is so split off and dissociated from everything else. But the computer could have the same impact on learning French. And what we see in the French classroom or in the mathematics classroom tells us nothing at all about difficulties we have in learning these subjects.

We have seen so clearly in our laboratory what happens in ideal conditions. What we have seen in so many instances in our children is that those kids have taken to mathematics so easily, have learned with such facility, that they are being slowed down instead of accelerated by the whole school process. The teachers know that too, but they don't know what to do about it.

I would like to give it a little theory and talk about dissociate learning. For most people in this culture, mathematics has no relation to anything they enjoy, or love, or do, or appreciate. It is in a box apart. We are told that some people (like scientists) use it in some magical way to make moonships of which you know nothing. This is dissociate learning.

By syntonic learning, I mean "It goes together with." Children learn a tremendous amount of stuff by syntonic learning, including a tremendous amount of mathematics. They don't only learn it, they invent it. Piaget is important for investigating the thinking of small children and finding some remarkable discoveries. Piaget has filled books and books and books full of things that children have discovered. If it were totalled and made into a curriculum, teachers would pass out in horror at the thought of the immense task. But the same would be true if you considered what a child learns in order to speak his mother tongue, or to manipulate his parents, or to know what is a funny joke. The fact is that children, until they get to school, are avid, eager, successful learners. Then, when they come to school, they learn that learning is not so good.

The point is that children do acquire, learn, construct, reinvent (or whatever the word for it is) a vast amount of mathematical knowledge (and other kinds of knowledge) before they ever come near the classroom. And this is not knowledge that is acquired in a dissociated way. So I would suggest that syntonic learning may be another good name for Piagetian learning, which is a kind of learning that happens without being taught, without a curriculum, quiz, or grade. And there is certainly a fantastic amount that is learned this way.

Why not everything? Why are there some things that seem to require such a different learning process. I would say that one of the reasons is that, although we have always known in principle what to do about it, we haven't had the technological infrastructure to realize the things that we've already done. Now the computer has brought us the technological infrastructure that can make possible a real intervention in the learning environment, one in which syntonic learning can be generalized to cover a much greater area. I hope we can make the most of it.