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This paper is based on a talk presented at Children in an Information Age: Opportunities for Creativity, Innovation, and New Activities (Sofia, Bulgaria, May 1987).

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Introduction

Everybody in this room would agree that we are moving into something called "the computer future," a future where everything will be different because of the presence of computers and other new technologies. In some departments of life, the computer presence is already visible. Coming here from my home, I passed through an airport and bought airplane tickets. The computer terminal has become an integral part of that transaction: you buy airplane tickets by dealing with somebody at a computer. In some of our airports in the United States, you don't even need the person. You can deal directly with the computer: put in your credit card, out comes the ticket.

These manifestations of the computer are perhaps superficial. They have not changed our lives very much. It even takes the same amount of time to get your airplane ticket. But there are other departments of life where nobody would say that the use of the computer is superficial. No one who owes his or her life to CAT scans in medicine would think that the role of the computer in transforming medical practice is a superficial matter. We are meeting here this week to talk about the computer in a department which, up to now, has been touched only quite superficially: learning, education, and the lives of children. The presence of the computer in this area will have a very deep impact—not only upon the nature of schools themselves, but also upon the whole of human society. The way that the computer enters into learning will play a determining role in the way that both technology and the larger culture evolve in the coming generation.

So we are entering this computer future, but what will it be like? What sort of a world will it be? There's no shortage of experts, futurists, and prophets who are ready to tell us—only they don't agree. The Utopians promise us a new millenium, a wonderful world in which the computer will solve all our problems. The computer critics warn us of the dehumanizing effect of too much exposure to machinery, and of disruption of employment in the workplace and the economy.

Who is right? Well, both are wrong—because they are asking the wrong question. The question is not "What will the computer do to us?" The question is "What will we make of the computer?" The point is not to predict the computer future. The point is to make it.

Our computer future could be made in very many different forms. It will be determined not by the nature of the technology, but by a host of decisions of individual human beings. In the end, it is a political matter, a matter of social philosophy and of social decision how we will remake and rethink our world in the presence of technology. When we talk about computers in education, we should not think about a machine *having* an effect. We should be talking about the opportunity offered us, by this computer presence, to rethink what learning is all about, to rethink education.

In past generations, education has been very much off on the side of the main stage of the world. In our universities, the schools of education are given second place. The prestigious departments are physics and molecular biology and mathematics and philosophy. Education? That's some minor subject.

In the political world, when statesmen meet at conferences and summits, they talk about matters of finance and arms and trade. Learning is off in the wings, to be discussed—if at all—in lip-service statements in opening speeches and closing ceremonies. But I think this is changing. One of the effects of these new technologies is that learning and education will move to the center stage—in its intellectual interest, in the opportunity and the need for profound study and research, and in the political arena as well.

We are already beginning to see signs where the politics of learning is becoming a matter of central stage and not something off in the wings. As we face a world of ever-accelerating change, it's no longer possible to have a concept of learning where people in their youth will learn the skills that they will apply through their lives. Learning has to be a continuous matter. Everyone pays lip service to this now, but soon it must also enter into the decision making at both the highest and lowest levels of all countries of the world. Who will prosper and who will not will be largely a matter of who is able to enter the computer future of learning.

My presentation is organized around four core ideas—two of which (*technocentrism* and *scientism*) I present as a warning of what we should avoid, and two of which (*educology* and *constructionism*) I present as a framework for developing a vision of where we should be heading.

Technocentrism

I coined the word *technocentrism* from Piaget's use of the word *egocentrism*—which does not mean that children are selfish; simply that when the child thinks, all questions are referred to the self, to the ego. Technocentrism is the fallacy of referring all questions to the technology.

In the proceedings of conferences on technology and education, there are questions like: Will technology have this or that effect? Will using computers to teach mathematics increase chilldren's skill at arithmetic? Or will it encourage children to be lazy about adding numbers because calculators can do it? Will using word processors make children become more creative writers? Or will it lead to a loss of handwriting skills? Will computers increase children's creativity? Or will it lead to mechanical, rote methods of thinking? Will the computer increase interpersonal skills? Or will it lead to isolation of children from one another?

These questions reflect technocentric thinking. So do all questions about whether this use or that use of the computer is the right one. "Does drill and practice improve children's performance in arithmetic?" "Does Logo lead to more mathematical thinking?"

These are interesting questions, of course, but they are not fundamental ones. It's not drill and practice—or Logo—that will achieve this or that result; it's how we use these things. But beyond questions about the most efficient way to teach arithmetic, there are questions that existed long before the computer—questions that have to do with general theories of education.

Long before the computer, the education world was divided into two camps. One emphasized the development of the child and the child's active construction of an understanding of the world. One might call these *child-centered* or *developmental-centered* approaches to education. On the other hand, in quite sharp opposition, are those who believe in a more curriculum-centered approach.

I want to quarrel a little with the title of this conference: Children in an Information Age. The title carries the danger of encouraging an information-centered approach to education—which is not very different from a technocentric approach. Thinking of the future as an information age certainly focuses on some exciting new developments. There is more access to more information than there has ever been before. But there is also a dangerous side from an educator's point of view: the danger of seeing the most important aspect of education as the providing of information—or even the providing of access to information.

One should make a sharp distinction between these two views of education. In one, the goal of education is to foster individual development. The other focuses on the information that the individual will acquire. Strongly related to this division is whether we see the goal of education as fostering independence and a sense of personal power on the part of the children.

The role that the computer can play most strongly has little to do with information. It is to give children a greater sense of empowerment—of being able to do more than they could do before. But too often, I see the computer being used to lead the child step by step through the learning process. Ivan Illich said the most important thing you learn at school is that learning only happens by being taught. This is the opposite of empowerment. What you ought to be learning at school is that you don't need to be taught in order to learn. This is not to say that the teacher is not an important part of the learning process. That teacher is, of course, the most important person there. But recognizing the importance of the teacher is very different from reducing learning to the passive side of being taught. This is the fundamental cleavage between theories of education: empowerment of the individual versus instruction and being taught.

In the past, I have inveighed against the phrase *computer-aided instruction*. One can criticize it from many angles. Right now, I only want to mention it as a symptom of a way of thinking. The fact that this phrase should have been so easily accepted by the world of specialists in computers in education shows that the emphasis in their minds is on the computer as an instructional device. This is one side of education, but the smallest and least important one. If we devote the computer only to that side, we will be wasting it. It can do much more.

The issues about how to use the computer in education reflect deeper issues of educational theory and philosophy. Long before computers, educators were split on the question of education as learning facts and skills versus education as personal development. The computer sharpens these existing cleavages in educational theory. Yet even these debates are reflections of still larger issues: of social theory and of social philosophy. What kind of people do we want? What kind of citizens? Do we want empowered individuals who will feel the power to make their own decisions and to shape their lives? Or do we prefer citizens who will accept the discipline of following the instructions and the programs that are set up for them by others?

Scientism

By *scientism*, I mean the attitude that sees all questions as scientific ones: resolvable by scientific studies. This point of view evaluates educational methods by measuring their effect on test scores.

Scientism makes the study of education appear easy: we will do little experiments to see whether this or that approach is better, experiments that isolate just one factor and keep everything else the same. Many people are enamored of these tiny experiments because they are statistically rigorous and seem to provide the kind of hard data one finds in physics. But that approach isn't feasible if you are thinking about radical change in education.

These kinds of studies do help to answer certain kinds of questions. If you are thinking about a small change—is it better to paint the walls of the classroom green or white?—you can do a little experiment. You can leave everything else the same and just change the color of the wall and see what happens. Even if you are asking whether it's better to reward success or punish failure, you can do a little experiment.

But we cannot decide by such measurements whether we want an open society or a totalitarian one. You cannot do a scientific experiment to decide whether you would like empowered citizens or instructed, disciplined automata. This is not a matter of science, it is something much deeper than that.

Educology

I borrow the word *educology* from Jonas Salk, a great American thinker and the inventor of the Salk polio vaccine, who has recently devoted his energies to thinking about a new phase, as he calls it, in human evolution. This evolution concerns individual creativity: the individual taking control of the creative evolutionary process.

The word *educology* reminds us that we need a theory of education. One might say we already have one. There's educational psychology; there's a theory of instruction; there are courses on the theory of how to administer schools. But these are not theories of education as a whole. They are theories of small aspects of what happens in the educational process. By focusing on these small aspects, these trees and shrubs, we have gotten lost in the jungle.

My diatribe against technocentrism and scientism points to one reason we need this new discipline of educology. We need a methodology different from those of other sciences such as educational psychology. To clarify this need, I'll take an example from my own work. People have asked, "What is the effect of Logo on learning mathematics—or on planning skills or whatever?" Some experimenters have come up with very positive answers, some with negative ones. But they are barking up the wrong tree. They are following the methodology of studying the effect of something by varying that one thing while you keep everything else constant.

Such methods do quite well for studying the effect of a drug or a treatment for plants. But in the case of Logo, one sees its absurdity by the fact tht the whole point of Logo is to make everything else change. One doesn't introduce Logo into a classroom and then do everything else as if it weren't there. Such an approach completely misses the point. Logo is an instrument designed to help change the way you talk about and think about mathematics and writing and the relationship between them, the way you talk about learning, and even the relationships among the people in the school: between the children and the teacher, and among the children themselves.

The traditional methodology for studying innovation in education may have been adequate at a time when only small changes were possible, when in fact one did change an aspect of the mathematics curriculum and kept everything else the same. But we need a different methodology altogether when we envisage radical changes in education. I'd like to make a few remarks about the scale of these changes.

It's important to realize that the scope of these changes could rival those we have seen in transportation, in communications, and in medicine. We used to move around on foot or on horseback; now we go by jet plane. We used to send letters or messengers; now we pick up a telephone to reach the farthest corners of the globe. And modern technology has transformed the practice of medicine as well. But in learning, in education, only small changes have happened thus far. Maybe it's an open question whether there can be changes of the same magnitude as have come about in these other fields—but we will never know without trying. I think this goal is what brought us together at this conference: I believe we can decide this question by giving it our best shot—by doing what we can to guide these deep, deep changes.

There are two sides of educology: one side faces towards society, the other faces the individual. When educology looks at new technology, it focuses on two kinds of questions, neither of which sees technology as having an effect. How does the society appropriate technology? And how does the individual appropriate the technology?

I've already touched on the social appropriation. My discussion of technocentrism raised the issue of whether the technology determines how people think, or whether how people think determines what technology they make. These issues are not being raised for the first time. They have fueled many discussions of social theory, economics, and politics. Karl Marx was engaged with Hegel in exactly that debate: Does the material determine the idea? Or does the idea determine the material?

We are faced with exactly the same issue. Very often, we are still at a technocentric stage of thinking. Our thoughts reflect a kind of primitive materialism: we think the technology will determine how we think. This is almost as crude as the primitive idealism that underlies the optimistic notion that thinking about education will determine how we practice it. Clearly we need a much more interactive kind of approach to these issues.

I like to use an analogy in order to get a handle on the problem. It's often helpful to look at some earlier technologies and see how they were appropriated. In particular, let's look at the history of the movies.

When the moving camera was invented around the turn of the century, the first thing people did with it was the same sort of thing you do with any new technological instrument: you try to do what you were doing before, and you try to do it better. So they put the movie camera in front of a stage, and they acted a play. Or if they were reporters, they went out into the streets and instead of taking notes with paper, they turned on the cameras. That is very different from the concept of the cinema, the movies, television, and the media as they have developed in our world. Cinema is very much more than putting a moving camera in front of a stage and acting out a play.

It's obvious that cinema is different, but in what way? It's important that we conceptualize the dimensions in which it is different. The one I want to emphasize and concentrate on today is that cinema is a new and different culture. It has its own language and metaphors. It has new roles for people. A movie producer? There was no such thing. A movie star? What's that? Also, the cinema entered into our social relationships: going out on Saturday night and all the rest of it. Cinema has become part of the wider culture; that's how it has grown. And this is what has to happen in education. We are talking about a new culture of learning, and how this new culture will grow in the new technological setting.

These themes are the challenge we face in the coming period—we need to think more deeply about the way in which technology will be woven into the change in education. To clarify this point, I will give an example.

Figure 1: Skeleton by Nicky B., Kris F., Doug R., David S.

This skeleton was made by four children who were nine and ten years old. This was done in the context of an experimental school: the Hennigan School which we operate in Boston as a collaborative effort between my research group at MIT and the Boston public school system. This school is in a very poor, working-class section of Boston. It's what we call an inner-city school. Most of the students have not done brilliantly and have little chance of doing brilliantly according to the usual statistics of who does or does not succeed in the school system.

We have introduced quite a large number of computers in this school, about one for every three students, so the students spend a lot of time with them. During the first six months of this experiment, our goal was to have every child work with the computer for one or one-and-a-half hours a day—with no other goal than mastery. So we taught the children programming in Logo, and how to write with the computer as a word processor. We didn't have any special-purpose software or instructional materials related to the computer—and we didn't have any idea of changing the curriculum because of the presence of the computer. Not at that stage. We wanted to see how the computer would enter into the culture of the school. How would the teachers pick up the computer? How would the children? The story I will tell is, for me, a typical example of how the computer can enter into the culture of an environment like this school.

This skeleton was made in February or March of 1986. Our Hennigan research began in September 1985, so this is about six months later. The teacher, Joanne Ronkin, has taught in that school for many years—and in January or February, it's time to do human biology with her class of fifth-grade students. She has found that studying the skeleton is a good jumping off point. The curriculum specifies only that she teach human biology. She has chosen the skeleton because of a personal affinity: she likes it.

In the past, she used a combination of several approaches to teaching the children about the skeleton. She had a book, and they read about it. She had a few bones that she showed them. She also tried to bring in somebody from the outside: a parent who was a nurse or occasionally even a doctor—although that was rare in that school. But usually somebody in a medical-related field could come in and talk about it. In the past, she always asked the children to choose a bone—each child chose one bone—which they would study and draw very carefully in their notebooks. Now this year, because the children had mastered doing Logo graphics on the computer screen, she said to them, "Well, draw your bone on the screen," instead of on paper.

The effect was quite dramatic—and it's important to notice that she didn't do anything exceptional. She just did what she had always done, only there was a different medium for drawing: the computer instead of pencil and paper. But a difference of medium can sometimes have a dramatic effect on performance. She was expecting each child to draw a bone, just as they had in the past. But to her astonishment, everybody opted to draw a whole skeleton. This was completely spontaneous and voluntary. Nobody suggested this or told them to do it. In this particular case, four students decided to collaborate because they recognized that drawing a skeleton with this kind of detail was impossible for one person to do, so they had to have four people doing it. And there you see a first way in which technological infrastructure changed the culture.

It changed the relationships between the people. The first change was between teacher and student, because these students were doing something that the teacher didn't know how to do. Their expertise at the computer had become greater than hers. Secondly, the relationships between the students themselves were different. Instead of the usual kind of competitive, isolated relationship between pupils that we often see in schools, where imitating somebody is copying and thus taboo and bad, these students got together because they recognized they could work better.

Once they got together, some new elements came in. They had to divide up the skeleton and decide what the natural divisions are. Also, if you do the arms and I do the vertebrae, we have to worry about how the arms and the vertebrae are joined together, and we have to worry about doing it to the same scale. So this new context was a natural entryway for many new aspects of *thinking* about the skeleton.

What was most dramatic, though, was the energy that was mobilized. The teacher changed her role in a very important respect. She no longer had to tell the children what to do. Instead of having to do something called "motivate the children," in the end she had to stop them—and she was quite unsuccessful in stopping them because they wanted to continue working on this, way beyond the time to go on to something else. They came at lunchtime, they came at recreation, they came after school; the thing caught on like a fire. And so the teacher, instead of having to be a sort of a slave driver and whip the students along, she had to become a conservative brake to stop them from overdoing.

In this case, what we put in was something very small—something that goes against all the accepted wisdom about the problem in education technology. You'll hear over and over again that the problem with using computers in schools is that we don't have the software, that it's so expensive making software. Here, the only software was a very good graphics system. The computer didn't know about skeletons, there weren't hundreds of programmer hours spent on putting information about skeletons into the computer. It was just a powerful instrument that empowered those students.

I'd like to emphasize one other aspect. This was called a biology class, but much more than biology was involved. All the students, without exception, became involved in wanting to make something beautiful. You can see an aesthetic aspect as well as the scientific and logical, and this aesthetic is equally important.

For me, this particular example has become a metaphor for something much more general. One of the worst things we do in our schools is compartmentalize. We cut things in bits. One of the worst cuts we make is dividing the aesthetic from the knowledge, from the science. This is a disaster, because the source of the children's energy is very largely in two areas that we see here: their social relations and their aesthetic drive. This is what produces the energy—and we cut this off. In the skeleton example, we saw it come back.

We also see individuality. Here's another skeleton [Figure 2]. This was created by a girl who decided she wanted to work alone. So her skeleton has less detail. It doesn't mean she didn't study very carefully to make it. There's a lot of expressiveness. Each skeleton has its own character.

Figure 2: Skeleton by Rachel C.

Figure 3: Skeleton by Sunny T.

So as well as being aesthetic in the sense of pretty to look at, we also have aesthetic in the sense of expressing one's view of the world. Just to make a point that styles are different, here's another one [Figure 3]. This child didn't want to draw a skeleton, and we know this child very well. In fact, one part of this research at the Hennigan School is that we really tried to get to know these children as individual people. This child is deeply concerned with language and with names of things. So in her skeleton project, she went to a lot of trouble to know the names of the bones. *Humorous* is quite humorous, of course. Nobody corrected her, but in the end she found out that's not the way to spell it. But it wasn't important how she spelled it. The point is that she had an intense experience because she thought of herself as putting the names of the bones on her computer screen so that the rest of the school would see, through her work, what their bones were called. So individual style becomes an important component of the experience.

This is another reason why it's wrong to ask, "What is *the* effect of *the* computer on *the* child?" It has *many* different effects on *many* different children, depending on what they are interested in. In fact, the children go in opposite directions; if you look at it statistically, the average comes out at zero. The children who are more language-oriented use language more. The children who are visually-oriented use visual and geometric representations more. The ones who like to plan in an obsessional way can become better planners. The ones who like to create freely in an expressionist way can do that better. If there is an effect in this environment, it is that each individual can follow his or her own style. You can become more yourself, you can become what you are, whatever that is.

Constructionism

I'd like to emphasize the idea of *constructionism* as part of a theoretical approach, as the other branch of the theory of educology. We need a social, historical theory to understand the way that technologies enter into society—how they are appropriated by society. We also need a theory about how they are appropriated by the individual.

The word *constructionism* is coined form two words. There is a psychological theory which I first learned to appreciate from Piaget, but one also finds it in Vygotsky and in other theorists. This theory says that knowledge is not transmitted like information in a pipeline. In fact, there is something called the theory of information that in many ways gives us exactly the wrong picture of education. Knowledge is not transmitted, it is *constructed*. Each individual must reconstruct knowledge. Of course, not necessarily alone. Everybody needs the help of other people and the support of a material environment, of a culture and society. But still, knowledge must be constructed—and that's what Piaget meant by the term *constructivism*.

Construc*tion*ism adds a second side to Piaget's idea of construc*tiv*ism. Constructivism is the idea that knowledge is something you build in your head. Constructionism reminds us that the best way to do that is to build something tangible—something outside your head—that is also personally meaningful. In the skeleton project, the children were *making* something. They were creating a skeleton on a screen. And because they were making something, they could mobilize their whole person: their aesthetic sense, their sense of a meaningful project, their sense of it being related to who they were as individuals and what their most important values were. The child interested in language saw what she was doing on the screen as part of a larger enterprise: she was influencing her comrades in the class and expressing herself through a project she could work on consecutively for many weeks.

This is what I mean about *constructionism*. She was creating something: a project that was rooted in her own sense of self. She was not sitting with little squares on paper writing meaningless numbers. She was not learning through a fragmented process where knowledge is chopped up into little pieces, and then you have to figure out how they go together.

I'd like to highlight that idea with one more example from the Hennigan School. In the case of the skeleton, what was constructed was something on a computer screen. Of course, some criticisms of computers in schools say that too much immersion in the world of electronic things—rather than physical things that you can feel and touch and smell—could be dangerous. I completely agree. So one theme of our work over the last several years, especially in this school, is to take informatics out of the computer. We use activites that are not directly related to the computer, activites that use real, three-dimensional, physical things. My favorite example, one that has shown the most dramatic results, is a project we call LEGO/Logo.

It uses Logo as a programming system, and the LEGO building blocks used by children to build all sorts of things. We've developed an interface between the two. You can build something out of LEGO—perhaps a vehicle with a motor and sensors such as light and touch—and you can connect it to the computer. You can write a program to make this vehicle do things, so you can get into a kind of control theory, a kind of robotics. This combines the constructionist principle that we use in the computer with the constructionist principle in the outside world of physical objects. A few incidents will illustrate some ways in which this can change the learning environment in what I think of as a constructionist basis.

My first example does not really involve the computer at all. We have developed a kind of model experience with LEGO/Logo. On the first day, we give the children a very definite assignment: to make a vehicle, any vehicle you like. Then we put the vehicle at the top of a sloping cardboard track, and we let it run down the track. Our first idea was to have them race, but that was unpleasantly competitive. Instead, each car runs down individually. When it reaches the bottom of the track, it runs along the floor—maybe just a little distance, maybe farther, depending on how you built your car. When it stops, you put a piece of tape on the floor and write your name on the tape.

What do you do next? You pick up your car and you start changing it to make it go further. *Everybody* does that. You don't need a teacher who says, "Now try to make it go further." It's in the nature of the situation that when it stops there, you say to yourself, "Why should it stop there?" And you try to make it go a little further. So you become involved in thinking about what you should change: what aspect? Well, some aspects are clearly irrelevant. Nobody thinks changing the color will make it go further. In fact, almost everybody thinks that changing the weight will make it go further. Most think they should make it heavier, but some think they should make it lighter. So in a certain sense, they are *reliving* a piece of the history of physics. Aristotle would have said it's the weight. Make it heavier and it will go faster and further.

But what Aristotle would have said isn't really important. In this class, the children start changing the weight. But in fact, the weight doesn't make much difference. As Galileo found out and as these children rediscover, you can't make any radical difference just by changing the weight. But they try all sorts of things—and this is re-enacting something else that Thomas Kuhn has taught us about the history of science. When your hypothesis seems false, you don't give up, you reinterpret it. If you thought that heavier would make it go further but that doesn't work, you think,"Okay, let's make it lighter." You're still using weight as your way of thinking. And if lighter doesn't work, you'll put the weight behind or in the front or lower or higher. You do everything you can with weight until eventually you realize that no, you can't do anything with weight, you better give that up. Besides, some other people are beginning to get another idea that's spreading in this group: that the crucial idea to think with is not weight but friction.

Very few of these children know the word *friction*, but they pick it up: it's *rubbing*. The parts are rubbing against one another, and that's the problem. This immediately leads you to reconstruct. You rethink your vehicle and make the thing simpler and simpler with less and less friction. Now the cars go really fast and far. So there's been a change in paradigm, a paradigm shift, in that little scientific community of children.

This is a marvelous setting for the learning of much about science. It's a much better way than learning the laws of motion as quantitative things, or the law of friction as the formula $F=\mu f$ or whatever. The point is that these children underwent a social process where in this community, there was a shift of paradigm. The knowledge they had was not a quantitative formula but a more important sort of thing: a paradigm, a way of thinking. Do you think in terms of weight? Or do you need to think in terms of something else? And when you've thought in terms of this something else, maybe you need to give it a name. This is where a teacher becomes important. "We'll pin it down. It's called friction. You can meet friction in many other places and so we can talk a lot about friction."

This is a different approach to learning science. It's similar to something that is often called "hands-on." But notice that this is much more than hands-on. It's not just that the children are doing something, they are doing something that comes from an inner motivation. Like the skeleton: it's not just that they made it. They made something that came from their own desire and was driven by their own sense of values. And here too with the cars and friction. So it's in the making of these cars—in the constructionism—that we create a context for a different way of learning about physics.

The car experience might last anywhere from one to three days—a day meaning a session of an hour or hour-and-a-half, and the next session might be next week. After two or three days, when this has run out of steam, we switch it and say, "Now make anything you'd like." By making these cars, they have learned some fundamentals of the syntax of putting together these LEGO pieces. They all know a little Logo programming from before. Now they start putting on motors—and by the way, we've noticed a very interesting phenomenon. Quite a few children think that to put a motor on the truck, you only have to stick the motor on. They are quite surprised that putting the motor on top of the truck doesn't make it go. So they make another kind of discovery: that the motor must be attached to the wheels.

So most of the class moves on to motorizing and computerizing. The next story I'd like to tell is about four girls—but it's also a story about all the people in the world who, for one reason or another, grew up with a sense of timidity about things technological or scientific or formal. The people in this story happen to be girls, and in many cultures, the girls are the ones who suffer most from this kind of inhibition. But of course, they are not the only ones.

So when we said, "Okay, make anything you'd like with it," some of the children—the macho boys particularly—went off and made these trucks and tried to make them more powerful and faster and so on. But these girls did not. Instead, they did what they already knew how to do with LEGO: they built a pretty house. The fact that LEGO is already familiar to the children is also important. LEGO is very widespread in America and in many European countries as well, which meant the girls could do something spontaneous: build an elaborate house with ornate walls and turrets and towers and windows.

What we began to see in that classroom was another reconstruction of an historical event. Earlier we saw the Aristotle versus Galileo split. This time, we are seeing the so-called "two culture divide." Here were these technocratic macho boys building their trucks. And here were these girls, the culture of art, building these beautiful little things. And so the familiar rift, the familiar chasm between these two cultures was being constructed in that class. What were they going to do? We watched.

Our purpose at the Hennigan School is not only to instruct or to teach, but also to understand in the spirit of anthropology. What was going to happen? What happened taught us once more that the role of the teacher should be to be sensitive and watch and wait and find the right time to intervene, because those girls did something much more clever than I would have thought of. Anything that I might have done to get them out of this trap would have been disastrous compared with what they did. After quite a long time, somebody noticed that in the middle of that house, deeply buried in it, there was a little light going on and off. A tiny little light.

These girls are very feminine in a traditional sense—they have bows in their hair and they giggle a lot. Despite the barriers, however, I believe that in their hearts, they *wanted* to appropriate the things technical and scientific that they see around them in their society—just as everyone does.

All children want to appropriate everything in the society around them. But these girls had a self-image of themselves as "I'm not the sort of person who can do that." And so they were inhibited. They had to find a way of taking hold of the technology almost without looking. What they did might be described as taking the technology by the "little end." They put this tiny little light inside their house and wrote the tinest little Logo program to control it. The program just said:

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on wait 10 off wait 10
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and they repeated that many times.

If anybody had said, "Do it, connect it to the computer," I think it would have had exactly the wrong effect. They *had* to do it when nobody was looking—when they weren't looking themselves, almost behind their own backs. But once they started, they had entered into the world of appropriating technology.

The next day, there were two lights in the house. And the next week, there were several lights going off in quite complicated patterns. The week after that, there was a Christmas tree turning. In order to make that Christmas tree turn, they had to do quite a lot of things. The LEGO motor goes very fast. If you try to put a Christmas tree built out of LEGO pieces on it, it will fly off immediately. So they had to think of gears—or pulleys in fact is what they did. They had to slow it down. They had to become involved in many issues that children of that age, eight and nine years old, find difficult and subtle.

So there they were. They had found their entrance way into the world of technology, of science and formal things, through this new technology which could be taken up in such a delicate and subtle way. It was so delicate and subtle that it needed these delicate and subtle girls to find their way of appropriating it and making it their own.

The theme I'd like to end on is a cluster of words around *appropriate*. Make it your own. Take it up. Make it part of your life and your thinking and your culture.

What does it mean, to *appropriate* something, to make it your own? We do a lot of experiments at the Hennigan School. For example, we ask children questions about what they are doing. One simple question and piece of research gave some results that illustrate this. Some of our graduate students asked the children, "What are you doing?" In the first few months, if you asked this when they were working with the computers, they would say, "computer" or "Logo" or "programming." But six months later, when you came to children and asked what they were doing, nobody said anything like that. They said, "I'm making a skeleton. Can't you see?" Or "I'm writing a story." Nobody talked about the computer anymore.

The computer had been absorbed; it had become part of the culture. This is not surprising. If you went up to a poet who was busy writing his poem and asked what he was doing, you'd be very surprised if he said, "I'm using a pencil." Of course he's using a pencil, but the pencil has become invisible. It's not there as a separate thing, it's part of his life. It's part of the world. You don't think about it. And so too the computer. We've only succeeded when it becomes invisible. That doesn't mean you don't think about it. You think about it when you need to, when you want to do something about it.

But you're thinking about what you want to *do* with it, you're thinking about that subject matter. This is part of appropiation, making it yours. It's like yourself.

Closely related to this word is another word: *love*. Einstein said, "Love is a better master than duty." This is often forgotten by many of the modern theories of education. There's a thing called cognitive science. I don't think the people who gave it that name meant any harm, but in psychology, *cognitive* means the thinking as opposed to the feelings, the emotions, the unconscious, the personality, the motivation. Cognitive science separates off the thinking as a separate thing. If you read the reports and you look at the kind of work that is funded by the government agencies, it's cognitive. But they're wrong.

They're wrong because the reason you need all those heavy-handed instructional methods is because you're trying to teach people something they don't want to learn. When they want to learn it, if you create the right intellectual environment, they learn it quickly and easily. So you can get 100 times more mileage by making those conditions in which the children will appropriate knowledge by falling in love with it.

And there's more. I had an interesting experience yesterday—a very touching experience—in a school here in Sofia. I visited a school where children were using computers and making programs. At the end, they said they wanted to interview me and they had questions. One of the questions was, "Do children anywhere else have such a great teacher?"

I was so moved, I didn't know what to say and I said something very clumsy and awkward, but I thought, "Isn't that wonderful?" There was something about the kind of work they were doing which made them feel this way about their teacher. Of course their teacher is a wonderful person, but we can create educational environments that bring out the love for the teacher and the love for everyone else there. Above all, even more than the love for the knowledge, there's this principle: that if you love what you learn, you'll get to love yourself more. And that has to be the goal of education, that each individual will come out with a sense of personal self-respect, empowerment, and love for yourself—because from that grows all the other loves: for people, for knowledge, for the society in which you live.