The idea the computers can and should belong to children as much as to adults has become widely accepted, to the point that few people would now consider it even controversial.

Nevertheless, this fact is as much a reflection of how much our society has changed over the last fifteen years as much as it is an established reality. As recently as the 1970's, the concept that computer technology could belong to children was considered truly revolutionary. If there is one person who is responsible for this change in our perception of the computer, it's Seymour Papert.

Within the world of education, Papert is best known as the pioneer who developed Logo, the programming language. But what people often forget is that Logo was created within the context of a broad program of educational reform, a program whose goal was what today would be called 'the empowerment of children' although at that time even the word 'empowerment' was not part of ordinary discourse.

Papert's notion was to put into the hands of children an unprecedented amount of power. It involved not only giving children access to the power provided by a knowledge of computer programming but also by knowledge of mathematics and science in general. Although Logo is widely used today, Papert's equally, perhaps even more, revolutionary ideas of reforming the way we teach math and science have yet to be taken seriously by more than a handful of visionary researchers. His ideas are more than ten years old; nevertheless they still represent the cutting edge in educational research, far ahead of work by later, but more conventional, thinkers.

What then is new in Papert's recent book, The Children's Machine (Papert, 1993)? The reader who is used to the excitement of Papert's earlier work may come away feeling disappointed. The new ideas presented in The Children's Machine are quieter, not as bold, not as daring. What impresses the reader is less what is new and more what has stayed the same. Papert and Logo have been the target of considerable criticism and controversy during the last decade, to the point that a less confident researcher would have made significant compromises. Papert has made some concessions to his critics. For example, Logo has been criticized in the past on the grounds that it favored boys but not girls (e.g. Hawkins, 1987). In his recent work, Papert has made a systematic effort to include more female research associates and to make Logo more 'user-friendly' to girls. Many of the examples in The Children's Machine are taken from domains of experience which are likely to be more familiar to women, such as dance, cooking and the names of flowers. Still, Papert's commitment to the Logo language and to his original conception of good learning and educational reform has, in its essence, survived intact.

If there is one, new, powerful idea in this recent work, it is the concept of 'constructionism'. The term itself is a deliberate attempt at the same time to appropriate and to parody the more familiar term 'constructivism'. Papert accepts most of the insights into the process of knowledge development proposed by Piaget and others who call themselves 'constructivists'; nevertheless he resists the association with abstract philosophy and academic pretense that the term 'constructivism' has recently acquired. Knowledge is gained, in his view, by rolling up your sleeves, getting your hands dirty, and trying to build something. The Children's Machine is full of anecdotes about the kinds of constructions, physical as well as intellectual, that children can produce, when they have access to a tool as rich with possibilities, for example, as Lego Logo.

Papert defines 'constructionism', by opposition, to a very different point of view that he calls 'instructionism.' The ideology of 'instructionism' is implicit in the work of most people who call themselves 'educational reformers' even though its presence is almost never recognized. The basic premise of 'instructionism' is that the route to better learning must be the improvement of instruction. The 'constructionist' attitude is very different, oriented toward reducing the amount of teaching. Papert recognizes, however, that you cannot simply eliminate teaching and leave everything else unchanged. What you teach, and how you teach must also be more powerful and more empowering. This attitude is captured in the African proverb: 'If a man is hungry you can give him a fish, but it is better to give him a line and teach him to catch fish himself.'

Papert offers mathematics teaching as an example. He writes: It is obvious that we in the United States (and most other places) are mathematical underachievers. It is also obvious that instruction in mathematics is rather poor. But it does not follow that the only route to better performance is the improvement of instruction. Another route goes via offering children truly interesting microworlds in which they can use mathematics...and think about it... If children really want to learn something, and have the opportunity to learn it in use, they will do so even if the teaching is poor.

The theme that children can learn what they need to learn without being taught recurs over and over in Papert's writing. It has been implicit since the beginning in the development of Logo and as well in related work such as the Micro-muse Project created by Barry Kort and his associates. The Children's Machine offers a rich collections of examples to illustrate concretely how this process can take place in practice. The reader should consider these examples seriously, think about them, and then
Papert's confidence to decide whether or not they believe that Papert's discipline generally is important that they should consider the examples which he offers extremely valuable as models of an effective and well-run classroom. And I agree that societies generally place too high a premium on discipline and have too little regard for students' own initiatives. Nevertheless in the end I find myself unable to accept Papert's ultimate conclusion. For this reason, I am afraid, Papert would be forced to include me in the camp of his enemy, the 'instructionists.'

As I see education, it is really a form of preparation for the world of work that students will encounter as adults. I think that most children, like most adults, are basically responsible and recognize most of the time the necessity of doing work that needs to be done. But they are doing it out of a sense of responsibility, and not because they necessarily think it is fun. It is important that they have weekends and after-school time to do things which they do out of choice, rather than out of necessity. It is also important that they receive some kind of tangible compensation for the time and energy which they devote to academics, rather than hearing trite phrases such as 'learning is its own reward' (so hard-working students don't require any further reward beyond knowledge itself).

In the final chapters of The Children's Machine, Papert develops the viewpoint, foreshadowed in his earlier discussion, regarding the need for a more 'biologic' alternative to the logical and rationalist images which, in his view, seem to dominate educational thinking so much at the present time, especially in the computer field. One very interesting chapter gives an overview of the history of educational computing from the perspective of its most famous protagonist. Elsewhere Papert is more future-oriented, concerned with fleshing out what a more concrete, biologic style of education in practice would be like.

In this context, he offers a tale of one incident from a workshop in which teachers were learning to program in Logo. A standard exercise for a novice learning Logo is to write a program to draw a house, and the standard method is to place a triangle on top of square. But for some reason - Papert to this day has no idea why - one of the students adopted a programming style that made use of curvy lines rather than the usual straight edges that form the walls of a sturdy house. Eventually the curvy lines came to represent smoke coming from the chimney. For this reason, Papert called this a 'smoky' style of programming in contrast with the traditional style that he called 'hard-edged.'

To illustrate the difference, he observed differences between the kinds of people who preferred the 'smoky' style and the ones who preferred the 'hard-edged' style. Research undertaken with the psychologist Sherry Turkle showed that the 'hard-edged' style is likely to be preferred by white males. The reason, in Papert's view, is that it is closer to the analytic, generalizable ways of thinking valued by traditional 'canonical' epistemology, which has come under fire from feminists as androcentric, from Afrocentrists as Eurocentric, and from the political left generally as representative of the thinking of dominating groups. Moving from the hard-edged to the smoky style involved a step away from an abstract and formal approach to one that invites all the words that Piaget... would attach to the thinking of younger children: concrete, figural, animistic, and even egocentric.' (p. 74)

Indeed there are weaknesses implicit in traditional 'hard-edged' thinking that people who practice it often fail to appreciate. It is a style of thinking that works well as long as everything is done exactly right but it is very unforgiving of even minor deviations from absolute precision. An alternative 'smokier' style is represented by the concept of 'managed vagueness' associated with the field of Cybernetics. Papert proposes that this style of thinking should be made directly available to children through teaching what he calls 'cybernetics for children.'

The nature of this more 'biologic' style of thinking is captured by comparing two ways of programming a mechanical turtle to circumnavigating a box. The traditional hard-edged style is to identify in advance the position of the box and write a program so that the mechanical turtle will go around this pre-defined region. In navigation, this technique is called 'dead-reckoning.' In contrast, the cybernetic style would be to equip the mechanical turtle with touch-sensors and to use a 'negative-feedback' circuit that tells the turtle to move away whenever a hard object has been hit. Papert makes the point that the cybernetic approach may feel less precise but it is in fact more universal. It is also typical of the methods that many living organisms actually use to navigate their way safely through space.

Papert devotes the last chapter of his book to metacontext of producing educational reform. He focuses his attention on creating a sketch of how one may conceptualize educational reform that will grow out of thinking in terms of cybernetic concepts such as 'negative feedback.'

The traditional 'rationalist' conception of educational reform involved producing a blueprint in advance and then advancing convincing arguments to persuade people that changing the system would represent improvement. In style, this approach to reform is similar to the 'hard-edged' approach to programming and the 'dead reckoning' style of navigation. An alternative, favored by Papert, is more like the 'controlled vagueness' of cybernetics. It would involve reacting to the contingencies of the moment rather than adhering strictly to some pre-established blueprint.

According to Papert, the problems which confront our education system today are in many ways similar to the problems of the Soviet economy which led Mikhail Gorbachev to initiate his program of 'perestroika' or 'restructuring.' Papert comments:

I would not like to argue that we actually live in a fully sensible economic system — far from it... What I do want to argue is that while our economic system, with all its faults, is above a threshold of functionality and the system functioned was below it, our education system falls on the same side of the line as the Soviet economy. We are living with an educational system that is fundamentally as irrational as the command economy and ultimately for the same reason. It does not have the capacity for local adaptation that is necessary for a complex system even to function efficiently in a changing environment (p. 207).

Papert recalls that in the old Soviet Union, supporters used to boast that every citizen had a job as well as a measure of social security. In a similar way, the large bureaucracies which presently govern the school systems are able to point out that every child receives an education and a certain degree of social protection. He considers the prospect grim of a future in which the goals of social equality are abandoned so that some people have access to knowledge while others are excluded. But neither is he encouraged by an image of a future in which society is governed by large, inflexible bureaucracies with little room for personal choice. As Papert sees the world, the only rational choice is to forge ahead in the encouragement of educational diversity. But in the process, it is important as well that we make a dedicated commitment not only to expanding its benefits to all who want them but also to making sure that those who choose not to want them are making an informed choice.