What's the big idea? Toward a pedagogy of idea power

by S. Papert

A key to understanding why School is what it is lies in recognizing a systematic tendency to deform ideas in specific ways in order to make them fit into a pedagogical framework. One of these deformations is described here as "disempowering ideas." The insight leads to a new direction for innovation in education: re-empowering the disempowered ideas. Doing so is not easy: it needs a new epistemology with a focus on power as a property of ideas and a challenge to the School culture. On the positive side, the insight also leads to a new vision of what technology can offer education.

One can take two approaches to renovating School[1]—or indeed anything else. The *problem-solving approach* identifies the many problems that afflict individual schools and tries to solve them. A *systemic approach* requires one to step back from the immediate problems and develop an understanding of how the whole thing works. Educators faced with day-to-day operation of schools are forced by circumstances to rely on problem solving for local fixes. They do not have time for "big ideas."

This essay offers a big idea in a reflexive way: the most neglected big idea is the very idea of bigness of ideas. I want to argue that the neglect of big ideas—or rather of the bigness of ideas—has become pervasive in the culture of School to the point where it dominates thinking about the content of what schools teach, as well as thinking about how to run them.

A learning story

The presentation of this rather abstract, theoretically oriented thesis begins with a concrete story.

Michael's side. Last fall I worked almost daily with a small group of deeply troubled teenagers. One day I brought a rattrap into our meeting place. Several boys, impressed by this ferocious-looking version of the familiar mousetrap, gathered around and began to make macho remarks: "you can break someone's fingers with that" and "that's nothing, *I've* set *bear* traps." After this kind of talk had died down, a quiet member of the group, whom I will call Michael, piped up with: "Awesome. That's a wonderful idea!" It took me a few minutes to be sure that he meant what I hoped he did: he was saying that the mouse trap is based on a wonderfully clever idea; he found it awesome that anyone could have invented it.

As I got to know Michael better I came to understand that seeing an idea where others saw an instrument of violence was characteristic of his mind. Ideas are what count for him. When we gave him the opportunity to work at building constructs out of mechanized/computerized LEGO** bricks[2] he showed a flair for taking up an engineering idea and embodying it in a variety of constructs. In this he differs from the intellectual style I have most often seen when students of all ages from preschool to college work with versions of the same construction material. Almost all give priority in their thinking to the performance or to the appearance of the product. For most the ideas are instrumental means to these

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functional ends. Michael often seems to work as if for him it is the end product that is instrumental to the means—a way of exercising a particular idea.

You might think that he is "the intellectual" of the group.

You would be led to a very different impression by his dismal school record. From the beginning he has been a regular habitué of "special education" classrooms. As seen through school tests he appears as an incompetent person: virtually illiterate, devoid of mathematical knowledge—in brief "a failure."

Working with Michael has increased for me the troubling awareness that failure in school can be the expression of valuable intellectual and personal qualities.[3,4] Many do badly in school because their style simply does not fit schools. Many react badly to school because its emphasis on memorizing facts and acquiring skills that cannot be put to use is like a prison for a mind that wants to fly. Perhaps the most saddening occurrence is when children come to understand, as many like Michael do, that they can buy relief from School's pressure by getting themselves classified in the category of "special ed." Often considerable problem-solving ability is brought to bear on getting oneself categorized as "dumb."

For many this is a deadly trap: once categorized in "special ed" it is hard to get out. I do not know how Michael's own relationship with school evolved. But I do know that it was perpetuated in a classical pattern: A kid who cares about ideas finds precious few of them in an elementary school where he is expected to learn facts and skills that he experiences as excruciatingly boring. He refuses to do it. School responds by classifying him as having trouble learning and so places him in special classes that are supposed to be easier. This is exactly the wrong response: "easier" means even more boring, even more devoid of ideas. And so begins a downward spiral. He comes to hate school and everything associated with it. What he really needed in the first place was work that is "harder" in the sense of having more intellectual substance and requiring more real concentration. The form this work might take will differ from child to child: in Michael's case it should certainly be some form of "idea work."

The opportunity to spend four hours a day over several months building technological objects gave Michael the chance to change his self-perception of not being "smart," which easily becomes a devastating consequence of the special education trap. It remains to be seen whether the change will be firm enough to reverse the effects of many previous years. I think the chances are good, but the moral of the present story is less about what Michael learned from us and more about what we can learn from his experience and whether we can apply it to give a better chance to the children now entering the education cycle.

There can be no panacea, but sometimes one has to think about one thing at a time and in this essay I focus on one strategy that happens to be well illustrated by Michael's case, although it applies equally across the spectrum of apparent academic abilities. I call it a *pedagogy of ideas*.

My side. I have been familiar for many years with the general pattern of failure and success shown by Michael; but working with him also helped me to a new understanding of a specific feature of the School mind-set which I now recognize (shocking as this may seem to many readers) as *a bias against ideas in favor of skills and facts—an idea aversion*.

It is close to 40 years since I fell in love with the idea that a technologically rich environment could give to children who love ideas access to learning-rich idea work, and to those who love ideas less the opportunity to learn to love them more. But many ideas are more easily loved than implemented. What is idea work? How can it be made accessible to young children?

During the 40 subsequent years, my initially vaguely intuitive belief has gradually taken shape. This essay presents some key episodes in my slow progress toward a fuller understanding, through many ups and downs and false starts along wrong roads, that in addition to the intrinsic difficulty of creating a theoretical framework for thinking about the pedagogy of ideas, a secondary layer of difficulty comes from having to fight resistance rooted in the anti-idea bias. But fighting resistance turned out to have a positive aspect: nothing has taught me more about the nature of School, or given more insight into prevailing cultural representations of School, of learning, and of childhood.

Perhaps the most important of these was switching from complaining to asking what I could learn from the fact that certain aspects of my 1980 book, *Mindstorms: Children, Computers, and Powerful Ideas*,[5] were widely ignored by commentators and practitioners.

Most of the many educators who found inspiration and affirmation in the book (as well as those who hated it) discussed it as if it were about *children and computers*, as if the third term was there as a sound bite, the kind of shibboleth that pervades the discourse of technology in education. I did not mean it to be that: I actually thought I was writing a book *about ideas*! What I had to say about children and about computers was important to me and useful to many teachers but was subservient in two ways to issues about ideas. As an educator and friend of children I saw new opportunities for children to understand, to love, and to use ideas that had previously been inaccessible to them. As an epistemologist I found that thinking about computers as mediators between children and ideas led me to a better understanding of several aspects of ideas—of some particular ideas, of the nature of ideas in general, and especially of how they come to inhabit people.

My reference to "idea power" in *Mindstorms* was essentially positive: I wanted to show that some very powerful ideas could be brought into the lives of children through the mediation of digital technology. The new insights reflect a greater humility in thinking about why there is a need to do so, but they can also be read as a criticism of School. I am not the first would-be educator to think that children should have access to the best available ideas—quite the contrary. Many have tried and many of the ideas I would want to bring in are already there. I have written elsewhere about ideas that are usually not (but should be) counted as appropriate for children to learn; here I concentrate on the ideas that have been brought into School's framework but have been deformed in the process. In a larger treatment I would discuss many forms of deformation; here I concentrate on the most significant, which I shall call *disempowerment*. Doing so opens new chapters of pedagogically oriented epistemological inquiry: How and why are ideas subject to disempowerment? How can we develop strategies for re-empowerment?

Sending ideas to school

The philosophy of education you can read between the lines of my story of Michael is resonant with the discourse of contemporary movements of school reform. Clearly it is in line with the *constructivist* bias toward learning by doing, with the situationist critique of dissociating knowledge from a context of use and with the *cognitivist* insistence on understanding the concepts behind the skills and facts that are the core of what school traditionally teaches (and especially what it *tests*.) But while it is resonant with the discourse of these movements, what I am advocating is very different. I applaud and share their intentions, but shall suggest here that in practice these would-be reform movements have allowed themselves to be assimilated to School's ways of thinking and in the end bolster rather than reform the fundamentals of the School mentality they set out to reform.[6]

How and why are ideas subject to disempowerment? How can we develop strategies for re-empowerment?

Consider Michael's relationship with school mathematics. Learning how to find the common denominator of a bunch of fractions is boring for him because he is not able to use it in any exciting way. It supports neither flights of the mind nor "hands-on" projects.

Enter a constructivist who says: Michael will have a better relationship with the manipulation of fractions if he discovers the rules himself. So situations are created (often with great ingenuity) that will lead children to "discover" the rules of arithmetic. But being made to "discover" what someone else (and someone you may not even like) wants you to discover (and already knows!) is not Michael's idea of an exciting intellectual adventure. The idea of invention has been tamed and has lost its essence. He wants to fly, but what this kind of constructivism offers him is more like decorating the captive bird's cage.

This failure of the constructivist to meet Michael's needs represents a double whammy of disempowerment. Jean Piaget's very strong idea that *all* learning takes place by discovery is emasculated by its translation into the common practice known in schools as "discovery learning." It is disempowered in part because discovery stops being discovery when it is orchestrated to happen on the preset agenda of a curriculum but also in large part because the ideas being learned are disempowered. For example, the idea of rules for manipulating numbers was historically one of the most powerful ideas ever and in the right context can still be. But no child would ever suspect that from its presentation in school as a rather boring routine. Setting ourselves the task of re-empowering the ideas being learned is also a step toward re-empowering the idea of learning by discovery.

The same double whammy is present when the excellent and potentially powerful intention, that knowledge is situated, turns into presenting manipulations of fractions in the guise of "real world" situations such as shopping at the supermarket. For Michael this contributes nothing to a sense of the power of the idea of fractions. He cares nothing about shopping in the supermarket and knows that in these days of automation at the checkout counter and unit prices on the labels, no one exercises arithmetic while shopping.

Or consider the cognitivist who says: Michael will have a better relationship with fractions if he understands the concepts behind them. This might be so if he could really understand how the invention of fractions was as awesome as the invention of the mousetrap and how the intellectual methods that were used to invent fractions could be used to make new inventions of his own. But the cognitivists are not trying to recreate the intellectual situation in which fractions were invented—and (as far as I can see) could not do so in the context of an elementary school math class. They simply want Michael to see the connection between one set of ideas about which he does not care and another similar set.

In brief, when ideas go to school they lose their power, thus creating a challenge for those who would improve learning to find ways to re-empower them. This need not be so. In the next two learning stories[7] we see elementary school children use computers to make a more authentic kind of discovery related to foundational ideas of arithmetic.

"You can put fractions on top of everything"

Debbie, one of the participants in a turning-point study by Idit Harel, had always been near the bottom of her class in anything related to math; her score on a standardized test of knowledge about fractions was in the bottom 10 percent.[8] For some school policy makers the principal moral of this story may be that "teaching to the test" is not the only way to improve test scores, which happened dramatically to Debbie's. For my present concerns the interesting facet is how a young poet (which is how Debbie saw herself) who despises math for its boring manipulations finds a congenial relationship with a mathematical idea when she can use it in personal way.

Harel's project was based on the creation of what she called a "software design studio" for fourth-grade students at the Hennigan School[9] in Boston. For an hour a day throughout the school year, these students worked with individual computers on an assignment to create a piece of educational software to teach something about fractions. The choice of what would be taught by the software was left entirely up to the individual. Many chose to teach to the test; much of the software could be described as drill in manipulation of fractions. Debbie's was very different.

At first Debbie was reluctant to participate. She hated fractions and asked to be allowed to use her computer time to illustrate poems she had written, and for the first weeks of the year she did this. Then one day she wrote in the journal the students were required to keep: "Fractions are everywhere!!! You can put them on anything!!!" That this had come as a surprising "aha" was clear from the exclamation points, the size and form of the writing, and the fact that it energized her to begin a project that would occupy her for the next few months. Her goal was to "teach" the world to see fractions as she now saw them: no longer boring marks on paper but a way of looking at the world. Her method was to present scenes in which she could guide the viewer to "see" fractions. The refrain was "they are everywhere." And although this is more interpretive, the approach she eventually found for her software project is in the spirit of her sense of herself as a poet.

Why is what Debbie did important? I give different answers to the test-oriented school administrator and to the epistemologist. The former may be willing to understand only the brute fact that Debbie herself, and statistically the whole class, actually did improve very significantly on standardized tests even when their projects did not bear directly on the skills being tested. The epistemologist gets a deeper answer coupled with a challenge: It is clear that in some very important but (at least for me) not yet clearly defined sense, Debbie was engaging with the *idea of fractions*—we need you to help us pin down just what this means, how it relates to the practical use of mathematics, and how we can make it happen more often.

Perhaps the epistemologist will respond by asking: "But how can I help? I am just an epistemologist, what do I know about how children learn?" In that case the next story might provide a helpful slant on the role of epistemology in understanding and promoting intellectual development.

The wonderful discovery of nothing

When I was a child I was told "The Hindus invented zero." I remember wondering what they really invented. What do you mean "invent zero"? I decided that what they invented was the round symbol we use for zero. Many years later a kindergarten girl[10] appropriately called Dawn taught me to understand what those Hindus really invented.

Dawn was working (or playing—I don't see much difference between these things when they are done well) at a computer using a version of Logo that allowed her to control the speed of moving screen objects by typing commands like SETSPEED 100, which would make them go very fast, or SETSPEED 10, which would make them go much slower. She had investigated some speeds that seemed significant, like 55, and then turned to very slow speeds, like 5 and 1. Suddenly she became very excited and called over first a friend and then a teacher to show something interesting. I happened to be visiting the class and shared the teacher's initial puzzlement: we could not see what Dawn was so excited about. Nothing was happening on her screen. Slowly I understood that the whole point was precisely that Nothing (with a big N) was happening. She had typed SETSPEED 0 and the moving object stopped. She was trying to tell us, but did not have the language to do so easily, that those objects that were "standing still" were nevertheless "moving"—they were moving with speed zero. Her excitement was about discovering that zero is also a number, speed zero is also a speed, distance zero is also a distance and so on. Up to that point zero for her was not a number. All of a sudden, it had become one.

One way to describe what happened to Dawn is that she discovered a property of zero she had not previously noticed. There is also a deeper description, which connects her experience with a theme of mathematical history that is more general and more fundamental than "the discovery of zero."

Number is not something that came into being historically in one act. It was progressively *constructed* by a series of extensions that is often schematically reconstructed in modern presentations as extending the idea of number as natural numbers (1, 2, 3 . . .) to include zero, then to include negative numbers, then fractions, real numbers, complex numbers, and beyond into the realm of "abstract algebra."

For me the most powerful idea in Jean Piaget's[11] complex lifework shows up in his belief that the development of ideas in children's knowledge systems parallels, not in detail but in general form, the way ideas develop historically. In particular the idea of number is not created historically or acquired by an individual child in an all-or-none fashion. Rather, it is progressively constructed. Most often the process is invisible and must be inferred by sampling what children can do with the developing idea; in this case I just happened to be present at a key moment in Dawn's construction of number. But this is not entirely accidental. I suggest that the constructionist use of computers increases the likelihood of such encounters by making the process more visible both to the informed observer and to the children themselves.

School's assimilation of Piaget

The difficulty is in the word "informed." Most people in the school world are not only not informed about this kind of Piagetian process, they are positively misinformed by a prevalent view of Piaget distorted by idea aversion.

The form of distortion is visible in the spate of recent news items telling how Piaget's constructivist views have been refuted by recent discoveries that babies come into the world with more abilities than he imagined. For example:

> Some of Piaget's most famous observations concern what he calls conservation. Dump a handful of beads on the table. Rearrange them in various ways—strung out in a line, heaped in a cluster, or whatever. Typically children at age seven do not believe that such rearrangements affect how many beads there are: if none were added and none were taken away the number is the same. But typically at age four children can be induced to say that there are more or less depending on the arrangement—most often they say "more" when the beads are strung out in a row and "less" when they are piled in a heap. Somewhere between these two ages children "construct" intellectual structures that underlie the later certainty of conservation.

The criticism, most noisily expressed in a recent book by Dahaene,[12] is based on ingenious experimental demonstration that babies can under some circumstances perceive the numerosity of small collections of objects: for example they make the same response to a set of three images whether these are clustered together or arranged in a line. In other words they show a rudimentary behavior that formally resembles conservation. It is unclear to me what Piaget would have made of this; my guess is that he would have been mildly surprised. But it is very clear to me that Piaget would have been very surprised (as indeed I was and still am) to learn that anyone regarded this experiment as relevant to the conservation of number. Indeed the fallacy in treating them as one phenomenon is so egregious that it needs explanation.

The psychologist is talking about behaviors. The epistomologist is talking about ideas.

I explain it to myself by following Piaget in making a distinction between psychological and epistemological ways of thinking. For psychology—and certainly for behaviorist brands of psychology—it *might* be considered legitimate to define conservation as the behavior of responding in the same way to objects in different arrangements. But an epistemological stance would immediately require making a sharp distinction between a baby's *perception of numerosity* of small sets and an adult's *certain knowledge* that however big the set, it will not be made more or less by rearrangement. The psychologist is talking about behaviors. The epistemologist is talking about ideas. *The interpretation of the baby experiment as refuting Piaget on this issue is another example of idea aversion*.

Let me be clear about the nature of my defense of Piaget. He was certainly wrong in his facts about what specific behaviors are innate. But equally certainly he was not wrong about the importance and the difficulty of the problem of explaining how knowledge evolves from whatever is there at the beginning to the very different and vastly more complex structures we have as educated adults. He was not wrong in his belief that epistemological analysis was needed to understand this evolution. And this incident confirms his belief that it was important to struggle (as he rather unsuccessfully did through his whole career) to have himself seen as an epistemologist rather than as a psychologist.[13] The fact that he failed and that the educational psychology community has thoroughly assimilated his work as "psychology" is one more example of its idea aversion.

Probabilistic thinking as an example of the disempowerment/re-empowerment cycle

If we gauge the power of an idea by the ramifications of the contribution it has made to the growth of knowledge, the idea of "probability" must score very high. It has played a key role in the development of rigorous procedures in all experimental sciences. It made possible the launching of social sciences with any pretension to be quantitative. It is at the heart of the Darwinian idea of evolution and plays a significant role in many other areas of biology. And perhaps most dramatically it became in this century a cornerstone of theoretical physics. Probability also scores high in terms of decisions that affect plain people in everyday-life decisions about medical, financial, and political matters. And so we could go on. It is therefore not surprising that designers of curriculum for math and science should suggest bringing probability into the classroom. But on the way it is subjected to the disempowerment suffered by most ideas when they go to school.

Typical of the way probability is being brought into the elementary curriculum is the following problem: Collect data about preferences for flavors of ice cream and compute the probability that Jane and Joe prefer vanilla to chocolate. The intention is that there should be a count of boys and girls who prefer each flavor and a calculation of the obvious ratios. To my mind this kind of problem is laughably far from bringing out the powerful role of probabilistic ideas in the history of thought.

To offer an image of re-empowerment I ask you to imagine a scenario in which a child grows up from an early age using computers in ways that lead to a high degree of technological fluency. I consider "time slices" at three different ages at which I present activities only slightly in advance of what one can quite commonly see today.

First we imagine a child at age five using a modern iconic form of Logo to make programs using animation and music for artistic effect. An iconic random generator is used to select colors, shapes, and actions. The probability distribution of the random variables can be modified by dragging "sliders." The child also likes playing a computer game in which decisions are not specific to actions, but to probabilities of actions. There may be no use of formal expression for manipulating probability, but a number of probabilistic ideas are being appropriated and intuitions developed.

My next time frame is at age eight. I imagine a child who has built a light-seeking vehicle using something like the "programmable brick"—a small computer marketed by LEGO as part of its Mindstorms** product line (which was named after the same book we have been discussing). The brick is programmed to decide, by comparing the outputs of two light sensors, whether the light source is more to the left or more to the right and cause the vehicle to make a small turn in the appropriate direction while moving continuously forward. On the assumption that there are no obstacles, it will eventually find its way to the light.

Now we make the situation more complex by supposing that there are obstacles that block the vehicle's movement without blocking its line of sight to the light source. The program as described does not "know" that the vehicle is obstructed and has no provision for corrective action if it did. So if an obstacle is encountered, the vehicle may stay forever spinning its wheels in place. What can be done?

One solution would be to give the little robot the means to know whether it is moving, register the presence of an obstacle, and try to circumnavigate it. Doing this would make the construct more complex both in hardware and in software, but it is still handily within the capability of an average technologically fluent child of eight to construct a robot that would be "smart" enough to perform very much better than the first "dumb" version.

The use of probabilistic reasoning enters the situation by providing another kind of solution. Suppose that the original program took the form of the following action repeated, say, every 100 milliseconds:

```
If sensor1 > sensor2 [turnleft 1 unit]
If sensor1 < sensor2 [turnright 1 unit]
```

Now consider what happens if we add another line to the program:

```
If sensor1 > sensor2 [turnleft 1 unit]
If sensor1 < sensor2 [turnright 1 unit]
With probability p turnleft x units
```

In the absence of obstacles the vehicle will follow a more erratic path, but if p and x are small it will still get to the light. On the other hand, if there is an obstacle the vehicle will not get into a trap of butting forever against it. Sooner or later it will randomly turn away from the obstacle and get a second chance at making it to the light by a different route. How well it works would depend on the nature of the obstacles and on the appropriate choice of the parameters. But in principle it would work in many situations.

My third time frame is at age eleven or twelve, at which point children are able to use probability to solve more analytic problems. I have observed such children in the following situations, which leads me to think that children of that age would handle far more complex cases if they had lived through the kinds of experiences I have been imagining for younger ages. Doing so would have given them far more experience with empowered probability, and a far higher degree of technological fluency, than they in fact had been able to accumulate.

The situations I want you to imagine at this age level are puzzles, such as guessing the probability of a coincidence of birthdays in a class of N students, and sampling situations, such as estimating an area on the computer screen by scattering random points on the screen and counting the proportion that fall in the area. For example, using the Logo turtle and a technique I call concrete programming, the birthday problem is handled as follows in a manner that the student would be able to invent fluently, drawing on previous experiences, without being specifically told how to handle this one.

The Logo[14] commands

```
setpos :start
fd random 365
```

will cause a turtle to move to one of 365 positions. The commands

```
setc "red
pd fd 0
```

will cause the turtle to leave a red dot at that position and

```
If colorunder = "red [Print "Coincidence stop]
```

will show that it has come to the same place a second time and stop the process.

So repeating this sequence 26 times will simulate a class of 26 people and tell whether there is a coincidence of birthdays. Repeating all that 100 times will tell you in percentage how often there were coincidences. If you want to automate the counting process in a concrete fashion you simply introduce another turtle, call it Counter, and replace

```
If colorunder = "red [Print "Coincidence stop] by
If colorunder = "red [Counter, fd 1 stop]
```

At the end the command:

```
Counter, show xcor / 100
```

will print an estimate of the probability of a birthday coincidence in a class of 26.

The sense of power comes here from being able to solve well-known or self-generated problems, puzzles, and paradoxes from personal knowledge using very general techniques that are all part of what I call "technological fluency."

Toward a theory of idea power

To tie together the threads of the discussion of the re-empowerment of probability, I give a short selection of criteria for judging the appropriate kind of idea power. Readers will easily see that this is not all there is to it: my selection is meant to be helpful to educators in their attempts to empower ideas, but it is intended mainly as a sketchy beginning of a theory and a challenge for further development.

With this qualification I am willing to say that in the context of the kind of experience adumbrated here, the idea of probability derives its power from the following properties:

First and most essentially, the young user was able to use the idea to solve a real problem that had come directly out of a personal project. Thus it is directly experienced as *powerful in its use*.

Second, the use made of the idea is directly connected with other situations in the world. It leads to the understanding of a large class of phenomena. Many simple creatures use mechanisms essentially similar to the probabilistic robot program; one might say that nature found the same solution and certainly biologists did. The Darwinian theory of evolution is based on ideas not very far removed. In short, the idea is *powerful in its connections*.

Third, the idea almost certainly has roots in intuitive knowledge the child has internalized over a long period, giving it a quality that in *Mindstorms* I call *syntonic* (borrowing the term from psychoanalytic literature). It is *powerful in its roots*[15] *and its fit with personal identity*. Using such knowledge is associated with a sense of personal power, absent from the use of knowledge that is experienced as coming from the outside, having qualities that in *Mindstorms* I call *dissociated* and *alienated*.

The third of these properties is the furthest from the usual frame of discourse of professionals talking about curriculum. But since it might be the most important as well as the hardest to convey, I venture another statement of the distinction between syntonic and dissociated or alienated. I put it in the first person, since this really is a subjective and personal kind of issue. *Every now and then I do something under pressure or out of error that gives me the feeling "this is not me." I fear that much of what we force children to do at school is like this and so not syntonic. Other times I have a wonderful feeling of being at one with what I am doing. This almost qualifies it as being syntonic. The "almost" refers to the possibility that these feelings might not be deeply authentic*.

Reopening the debate: Should children program computers?

In Mindstorms I made the claim that children can learn to program and that learning to program can affect the way they learn everything else. I had in mind something like the process of re-empowerment of probability: the ability to program would allow a student to learn and use powerful forms of probabilistic ideas. It did not occur to me that anyone could possibly take my statement to mean that learning to program would *in itself* have consequences for how children learn and think. *But I reckoned without idea aversion*. When the reference to ideas was filtered out of my claim that *Logo could help children by carrying ideas*, what was left was a claim I never made that *Logo would help children, period*. I was amazed to find that experiments were being done in which tests of "problem-solving ability" were given to children before and after exposure to 20 or 30 hours of work with Logo. Papers were written on "the effects of programming (or of Logo or of the computer)" as if we were talking about the effects of a medical treatment.

The difference between these two conceptions of the role of programming is of the same kind as the difference between the two interpretations of Piaget: in both cases the crucial difference is between primacy of the epistemological (talking about ideas) and primacy of the psychological (talking about how a person is affected by a treatment). I do not mean to dismiss the "treatment" studies as without value. For many children the opportunity to program a computer is a valuable experience and can foster important intellectual development.[16] But encouraging programming as an activity meant to be good in itself is far removed, in its nature, from working at identifying ideas that have been disempowered and seeking ways to re-empower them. It is even further removed from picking up the challenge to expand and deepen the theory of idea power sketched in the previous section. In my discussion of Michael, I suggested that what would benefit him would be better support for idea work. What I am suggesting here is a program of idea work for educators. Of course it is harder to think about ideas than to bring a programming language into a classroom. You have to mess with actual ideas. But this is the kind of *hard* that will make teaching more interesting, just as idea work will do this for learning.

Conclusion

When I was asked to review the book by David Tyack and Larry Cuban[6] on the history of school reform, I chose the title "Why School Reform Is Impossible,"[17] and my analysis of the idea aversion inherent in the culture of school reinforces the idea that it is impossible. But to say that *reform* is impossible does not mean that *change* cannot take place. Biological evolution is an example of change that does not come about by reform. More to the present point, while some educators might think of themselves as "reforming" the thinking of the child, constructionists see the change in the growing mind as a process that can be influenced and that often needs to be tended, but that in the last analysis follows its own laws of development.

So, too, the mega-change in education that will undoubtedly come in the next few decades will not be a "reform" in the sense of a deliberate attempt to impose a new designed structure. My confidence in making this statement is based on two factors: (1) forces are at work that put the old structure in increasing dissonance with the society of which it is ultimately a part, and (2) ideas and technologies needed to build new structures are becoming increasingly available. I hope that publishing this paper will help both factors. Public discussion of the idea-averse nature of School makes the dissonance more acute. Public access to empowered forms of ideas and the ways in which technology can support them fertilizes the process of new growth.

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Cited references and notes

1. I use the word School with an uppercase S to refer to an abstraction to which individual schools conform to a lesser or greater extent. This distinction is discussed more fully in my book *The Children's Machine*, Basic Books, New York (1992).
2. The key hardware used is the RCX™ "programmable brick" that forms the core of the LEGO Mindstorms line of products. Software is a subset of Logo ("Yellow Brick Logo") that has not been made commercially available. For latest versions available to researchers see www.learningbarn.org.
3. H. Kohl, '*I Won't Learn From You*': *The Role of Assent in Learning*, Milkweed Editions, Minneapolis, MN (1991).
4. L. J. Pallidino, *The Edison Trait*: *Saving the Spirit of Your Nonconforming Child*, Random House, Inc., New York (1997).
5. Basic Books, New York (1980).
6. D. Tyack and L. Cuban, *Tinkering Towards Utopia: A Century of School Reform*, Harvard University Press, Cambridge, MA (1997). I am not sure whether it was Tyack or Cuban who is responsible for the apt summary: Reforms set out to change school; but in the end it is school that changes the reforms.
7. Readers who follow my work will recognize the next two learning stories and may be inclined to skip over them. Don't. They have a different twist here.
8. I. Harel, *Children Designers: Interdisciplinary Constructions for Learning and Knowing Mathematics in a Computer-Rich School*, Ablex Publishing, Norwood, NJ (1991).
9. The project was made possible by the donation by IBM of several hundred computers, which allowed the installation of what was then an exceptionally large number for a school.
10. In the Lamplighter School in Dallas, Texas.
11. Jean Piaget is often credited with being the founder of the twentieth century study of the intelligence of children. See my essay on Piaget in www.papert.org/works.html/ for a brief assessment of Piaget as far more than that.
12. S. Dahaene, *The Number Sense: How the Mind Creates Mathematics*, Oxford University Press, Oxford, UK (1997).
13. Piaget's preferred name for his major field of work was "Epistemologie Genetique," which he sharply distinguished from psychology, which he thought of as a neighboring field in which he sometimes participated. However since the community that accepted him most readily was that of developmental psychology he sometimes succumbed to its blandishments and allowed its name to be applied to all his work.
14. The Logo commands should be sufficiently self-explanatory for any reader to follow. The version of Logo used is MicroWorlds, published by Logo Computer Systems Inc.

15. In his recent MIT Ph.D. thesis, *Technological Fluency and the Art of Motorcycle Maintenance*, David Cavallo refers to a cognate trio of properties as "roots, shoots, and fruits."
16. Note the word "can." Some studies showed positive effects; some did not. Methodologically the positive reports have the merit of describing something real even if it was not what I had in mind. The negative ones only proved that under the particular conditions of that experiment, nothing happened that could be measured by the particular tests used. It is a remarkable commentary on the culture of the educational psychology community that some of these were widely cited as proving that Logo has no effect.
17. *The Journal of Learning Sciences* **6**, No. 4, 417–427 (1997); available on line via www.papert.org/works.html/.

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