THE REAL MEANING OF HANDS-ON EDUCATION

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Editorial Introduction

Last year, Dr. Frank R. Wilson, a leading neurologist in this country and medical director of the Peter F. Ostwald Health Program for Performing Artists at the University of California School of Medicine in San Francisco, published a remarkable book, entitled *The Hand: How Its Use Shapes the Brain, Language, and Human Culture* (New York: Pantheon Books, 1998)
It is a special privilege for the Waldorf *Research Bulletin* to carry the following article by Dr. Wilson which presents some of the central arguments of his book.

Dr. Wilson is not a Waldorf educator, and, in fact, comes to his subject from a different perspective than that of Waldorf education. Waldorf teachers and parents will, nevertheless, find a striking convergence between the research and insights Dr. Wilson presents and the similar emphasis in Waldorf education on the intimate connection between the human hand and its activity and the development of creative thinking and language capacities. More than that, they will also find themselves carried further in their understanding of this all-important relationship by an author who joins his scientific, neurological expertise with a deep humanistic concern and wisdom.

Two points in Dr. Wilson's article will, perhaps, be of special interest to Waldorf educators and parents, and to anyone, for that matter, interested in the education of the whole human being. The first is the relation between the capacities for creative thinking and language abilities and "the interaction of the body with the world." Recently, Johannes Kiersch, a leading educator of Waldorf teachers in Germany, has written: "[Early language] achieves its individual form not through participatory imitation, but through the type of motor activity peculiar to early infancy. In several lectures of 1923 and 1924 Rudolf Steiner describes in what subtle ways the human capacity for speech is predisposed by the occurrence of certain leg, arm and finger movements. Thus he maintains that the structuring of language in sentences is anticipated through vigorous, regular movements of the legs, good pronunciation through harmonious arm movements, and a sense for the 'modification' of language through the child's experiencing the life in its fingers." (I. Kiersck, *Language Teaching in Steiner Waldorf Schools,* 1997, pp. 34-35). Dr. Wilson's work corroborates this emphasis on the relation between bodily movement and thinking. Moreover, he brings out in fascinating detail the pivotal role of hand movements in particular in the development of thinking and language capacities, and in developing deep feelings of confidence and interest in the world—all together the essential prerequisites for the emergence of the capable and caring individual.

Dr. Wilson writes, "If the hand and brain learn to speak to each other intimately and harmoniously something that humans seem to prize greatly, which we call autonomy, begins to take shape." In this light the important presence of handwork and the crafts in Waldorf education is not a frill for those who like that sort of thing, but are essential to the full development of the creative intellectual, emotional, and social capacities of the growing child.

The other point to which we call special attention is Dr. Wilson's timely caution on the serious threat posed to the thinking and emotional capacities of the developing, school-age child by the too-early introduction of computers in education.

We are very grateful that Dr. Wilson has made this version of his article available for the *Research Bulletin.*

Douglas Sloan, Editor

Presented at the Institute for Development of Education Activities (IDEA) Los Angeles, Atlanta, Appleton, Denver — July 1999

(Revised for publication by the Waldorf *Research Bulletin,* October, 1999)

In 1984 I was invited to address the annual meeting of the Music Teachers' National Association, where, speaking not only as neurologist but as a parent who had observed the impact of music education on his own two children, what I told music teachers was that they *were* doing absolutely the right thing for children in their work. Now that my kids are safely out and on their own, I have had the pleasure during the past year of meeting with teachers to talk about my new book, and of telling them how the work on that book not only reinforced my feelings about music education, but brought me to a new set of ideas about the education of children which has caused me to modify my message somewhat. The new message is more about students than about teachers, and simply put, it is this: there is nothing wrong with the learning tools that evolution placed, quite literally, in the hands of our children. At the end of this hour I hope to have made it clear to you why I know this to be true, and I hope further to have given you cause to question some of the claims made concerning the benefits of advanced technology — particularly computers and the Internet — in the education of children.

One of the reasons I agreed to give this talk is that music and arts teachers aren't the only ones having to fight to keep their programs alive. Just a few months ago, for example, I was asked by a science writer whether a brain scan might show the benefits of Waldorf education. It is obvious why this kind of thing is happening: The Waldorf teachers and even the auto and wood shop teachers have joined the ranks of the music and arts teachers, all of whom are losing their place in education and hoping that someone will find irrefutable scientific proof that what they do is good for children's brains. None of them hide what scares them: parents want their kids to be computer literate, and politicians want to spend their school money on the Internet.

Not quite two years ago, Douglas Sloan, Professor of History and Education at Columbia Teachers' College in New York, convened a conference there on *The Computer in Education.* He has kindly shared with me several of the still unpublished manuscripts from that meeting, from which I will quote briefly. The first passage is from the paper given by Edward Miller, a former editor of the *Harvard Education Letter,* that reminds us just how complex and pervasive are the effects of modern culture on educational practice:

> Historically, public schools in America were justified as necessary for democracy: without education, Jefferson and other founders of the nation argued, people could not be trusted to act as responsible citizens, But economic advantage has now almost completely replaced democratic ideals as the reason for education. Parents don't say they want a good education for their children so they will be solid citizens: they want their kids to be able to get good jobs.

Everyone has been caught up in the frenzy to bring computers and communications technology into the schools, and as a result it is widely predicted that traditional teaching — the highly individualized, personal teaching of hand-based skills in particular — is done for. The painful irony of the situation is that many faithful practitioners of these "old fashioned" methods hope that a computer-based brain imaging technology will somehow come to their rescue. Unfortunately, brain scans aren't going to help the Waldorf or the shop and art teachers in this fight any more than they helped the music teachers a decade ago. These tests just weren't designed to answer that kind of question.

So we have arrived at an interesting time in education: fundamental premises about the purposes of education can no longer be taken for granted — technology has not simply changed the way we do things, but our reasons for doing what we do. And there is a growing atmosphere of urgency and determinism associated with the advocacy of educational technology: the business community and the government are not going to tolerate slackers in the high tech millennial extravaganza engulfing our society.

Should you play ball? Can you afford not to? I don't know the answer, but I will say this. The new promised land is already beginning to show its darker side, and this might not be a bad time to ask whether a massive investment in computers and a computer-centric curriculum is the correct strategy for schools to prepare young people for the Darwinian cyberworld that awaits them.

Let me share an interesting statistic with you. 45% of the work force in California have been in their present jobs for 2 years or less. Part of the explanation for the increasing mobility of the modern industrialised/computerised workforce is that it no longer makes sense for corporations to groom employees for long-term careers. Every job is temporary now. This change is undoubtedly good for business, but as a physician I have recently had the privilege of seeing what the wholesale homogenising and modularising of employees can do to the human body and psyche. The best and the brightest of the modern work force — who also happen to be the poster children of the modern education system — are fast becoming denizens of what is called the cubicle culture and are at high risk for professional disorientation, social isolation, chronic anxiety, battle fatigue, paranoia, and wistful fantasies about finding a job that will give them a sense of accomplishment. High achievement in education provides no protection whatsoever — engineers, architects, computer scientists, accountants, doctors and lawyers are just as vulnerable as secretaries, postal clerks, and telemarketers.

Now let's look at that same mobility statistic from your perspective. Let us assume for the moment that you are blissfully unaware of what befalls your prize students once they enter the work force. How in the world do you design an educational program that will prepare kids for a working life in which they can expect to change jobs, or even careers, at least once every 3 or 4 years? I know that you all like to talk about "paradigm shifts" in education. But given what is happening in the working world, I think we can say that the age of paradigm shifts is long gone: we now jive in the age of paradigm avalanches. I wonder how those of you trying to prepare kids for such a future can sleep at night. What in the world are you supposed to do to keep the education train running, and where are you supposed to lay tracks that won't disappear under the next avalanche?

If I were a professional educator, I might argue that you should just stop making plans. Disconnect the phones, put everyone over twenty-five on leave and turn the schools over to the soft drinks, athletic equipment, and cosmetics companies to run over the Internet. What have you got to lose? But I am not a professional educator — and I certainly do not mean to trivialize the problem. There is a serious point I need to make, and I hope you will take it seriously: while it is true that organized institutions certainly can and do formulate educational objectives aid environments, they neither invented nor can they control the learning process. Biology gets that distinction. To be precise, primates have been systematically and successfully educating their young for over 30 million years, a span of time equivalent to 300 end-to-end repeats of the entire 100,000-year history of our species. Therefore I would argue that if your focus as educators is on the child, you do not need to look 50 or 20 or even 5 years ahead to keep your curriculum or your methods from becoming obsolete. No matter how loudly the relevance messages are broadcast, or the advent of the information age is proclaimed, the truth is that not even the companies at the very top of the technology food chain can predict what they will need in the way of skills in the next generation of employees, nor for how long they can afford to hire people with any particular set of skills. The workplace, in other words, is reverting to exactly the kind of metaphoric jungle which operates according to Darwin's classic rules of survival in a high risk, unstable environment.

The delicious surprise is that an uncertain future is precisely what our earliest ancestors faced —

indeed, the absolute certainty of an uncertain future was a major driving force behind several million years of hominid evolution which produced the particular model of the primate brain which modern humans happen to possess. The remarkable success of humans as a species on this planer depends to a very large extent on how the young develop their understanding of the world — that is, upon the rules which permit them to pass from immaturity and dependency to a state in which they can take care of themselves and bear and raise their own children in an uncertain world, in the company of others with whom they must learn to cooperate. These survival rules are quite robust. They were worked out over *millions* of years and placed in safekeeping in our genes. Organized institutions with a stake in education can either accept that reality, harness and exploit it, or ignore it, or even actively oppose it in some way. But until such time as the Artificial Intelligence movement takes over the world and genetic rearrangement of preschool children becomes the norm, the young of our species will respond to their environment and will advance their own skills and understanding according to the same basic plan provided to every new *Homo Sapiens* for at least 100,000 years. The developmental rules which define us as a species will do this no matter what any so-called Education President thinks or proposes as a tactic to improve on, or undo, what biology has given each and every one us in the form of native curiosity and learning capacity.

Another version of this same anthropologic perspective emerges from recalling that, without exception, every student who enters a classroom comes with quite a pedigree: he or she is no less than the present incarnation of 30+ million years of unbroken field-tested, continually evaluated and updated strategies for adaptation to an environment that has a consistent record of hostility to the incompetent.

A recognizable human pre-history began when advanced tree-dwelling primates started what is called the anthropoid suborder, and after 20-25 million years of experience with life in the trees — which is to say between 5 and 6 million years ago — as the climate changed and forests started disappearing, some of these animals moved to the ground. These were the hominids, descendants of the first anthropoids, or simians, to stand upright and walk on their feet.

As Darwin first commented 150 years ago, the upper limbs which had evolved in simians to provide for efficient locomotion and for foraging above ground were no longer needed to support body weight. For the first bipeds, who found themselves no longer needing the arms to walk along or swing under tree branches, evolution might have recognized this reduced functional demand in a number of ways. For example, reduced need for hand and arm skill could have led to a much smaller arm, perhaps something like what the kangaroo has. Alternatively, if the hominids could have survived on the ground by gathering fruits, nuts, and insects, our ancestors might have kept the arm as it was anatomically but surrendered the neurologic capacity for aerial gymnastics. That is approximately what happened to the gorillas, who have magnificent arms and hands that nevertheless are never used to manufacture or manipulate tools of any kind.

That the hominids did *not* become land-bound animals with withered arms or indolent lifestyles is almost certainly because they were small animals, and the habitat they entered was no palmy, fragrant Eden: it was a dangerous, sudden-death battleground dominated by powerful and hungry predators. In other words, our ancestors established a place for themselves because they found not less, but more, for the arm and hand and the brain to do. Indeed, based on what we now know of our own early history and the way that history is written into the human brain, our ancestors staked everything on skilled use of the arm and hand.

The commitment to that specific strategy, the reinvention of the arm and hand, probably began with Lucy. Who was she? Lucy is the name given to nearly the oldest and certainly the best known direct human ancestor, whose anatomic uniqueness led her and her species *(Australopithecus afarensis)* to be identified as among the earliest hominids. She was discovered a little over 25 years ago in east Africa by a young anthropologist, Donald Johanson, on the last day of the first field expedition of his career. A small fragment of an arm bone was sticking up through the dirt and Johanson noticed it. In a very happy mood in their camp that night Johanson and his friends were listening to the Beatles playing *Lucy in the Sky with Diamonds,* and they immediately decided to name their find, who was a female, Lucy. Considerable research over the past 20 years has established that Lucy lived about 3.25 million years ago. She was about the size of a chimpanzee, she had a brain volume of 400 cc, which is about 1/3 the size of the human brain, she walked uptight, and she had some unusual features in the structure of her hand and wrist. It was not like the modern human hand, but it was not like a chimp hand, either.

What we have learned about her hand, largely through the remarkable studies of the American anthropologist Mary Marzke, is that a few small anatomic modifications would have had a dramatic functional impact on the capacity of the hand. The thumb was longer in relation to the fingers, and the index and middle fingers could rotate at the knuckle joint. This change gave Lucy a new grip, which we call the 3-jaw chuck — this is the same basic grip used by baseball pitchers. So Lucy would have been able to hold larger stones between the thumb and index and middle fingers, and could have thrown them overhand, just as a modern baseball pitcher can. She could even swivel her hips to accelerate the speed of a thrown projectile. What she probably lacked was a computational system to turn all that novel manipulative potential into a ballistic system — so far as we can tell, she did not have the brain that would have transformed her hand and arm from a feeding and locomotor system to a weapons platform. But that is exactly what her descendants, over the next a couple of million years or so, managed to develop.

And that is not all our post-Australopithecine ancestors managed to accomplish. One of the most interesting aspects of the hand story has to do with the remarkable tendency of biologic systems to continually modify and adapt whatever is already in place when it is beneficial to do so — small changes can lead to unintended and sometimes monumental innovations. For the hominids, the small changes in wrist and hand structure led to significantly improved throwing, and eventually to a complete reorganization of the brain. Being able to hit a target with a stone depends most of all upon the timing of its release. Whenever it was that Lucy or her descendants began to rely upon this new hand to launch rocks at prey or at other predators, they also started building a supremely precise clock to control the activity of muscles in the arm and hand. And once thc hominids began to be sharpshooters, evolution began to play with hemispheric specialization in the brain. We can now say with considerable confidence that almost the entire set of distinctive human motor and cognitive skills, including language and our remarkable ability to design, build, and use tools, began as nothing more than an enhanced capacity to control the timing of sequential arm and hand movements used in throwing.

As far as anyone can tell, Lucy's family — *Australopithecus afarensis* — was the only living hominid species in Africa for nearly one million years, so perhaps she did try her hand at pitching. Without question, based on the archeologic and anthropologic record, and on the way the human brain is now configured, the australopithecines and their descendants came to depend increasingly on manual skills in their daily lives, and inevitably those who excelled at those skills increased their own chances of survival. Somewhere between 200,000 and 100,000 y.a. the hand had reached its present anatomic configuration, the brain had tripled in size, tools were more elaborate, there was a complex society based on the organization of relationships, alliances, ideas, and work, and we started calling ourselves *Homo sapiens.*

I said earlier that the australopithecene hand was not fully modern. What it lacked was the ability to move the ring and small fingers across the hand toward the thumb — a movement which is called ulnar opposition. Ulnar opposition is a prime example of a small anatomic change with monumental consequences, because it greatly increased the grasping potential and manipulative capacity of the hand. Ulnar opposition made it possible for the thumb to powerfully hold an object obliquely against the palm, as we hold a hammer, a tennis racquet, or a golf club, or as a violinist holds the neck of the violin. This new grip has been called the oblique squeeze grip, and it would have been a major advantage in close combat because in this hand a club could be held tightly and swung on an extended arm axis through a huge arc

But ulnar opposition also meant that the hand could conform itself to a nearly infinite range of object shapes and could orient and control them, precisely, delicately, or powerfully if need be. Small objects could be taken apart and put back together again, or made into entirely new objects that could themselves be connected, taken apart, revised, reconnected, and so on.

Since it does not seem likely that the brain's remarkable capacity to control refined movements of the hand would have predated the hand's biomechanical capacity to carry out those movements, we are left with a rather startling but inescapable conclusion: it was the biomechanics of the modern hand that set the stage for the creation of neurologic machinery needed to support a host of behaviors centered on skilled use of the hand. If the hand did not quite literally build the brain, it almost certainly provided the structural template around which an ancient brain built both a new system for hand control and a new bodily domain of experience, cognition, and imaginative life.

Anthropologists remind us that the social structure of the hominids was profoundly influenced by the manufacture and use of tools. The hand had long been an instrument for social interaction among primates through ritual grooming, and with the advent of cooperative tool manufacture and use, skilled hand use became associated with an open-ended mix of diversity *and* specialization of skill, which over time greatly strengthened and enlarged the social foundations for human survival, as well as creating a need for greatly expanded and refined methods of communication. What evolved in hominid life, in other words, was nor simply a new and clever use of the hand, but a life of shared trust and commitment, based on a realization that life for the individual takes its course and acquires its meaning from and within the community.

Let me briefly summarize what I have said so far: any human skill, in both its abstract and its concrete sense, is a river reaching back into the deep hominid and primate past. It is composed of far more than muscles, nerves, joints, reflexes, and brain circuits. It is part of the whole, almost indescribably long story of hominid and human evolution and represents the unfolding in individual humans of genetically based and culturally enhanced strategies for our survival. Trial and error, inventive tinkering and design, major innovations in brain operations to transform two hands into a cooperative pair, and to permit the hands to signal, reach, and even tell stories through mime and gesture all became part of the evolutionary success story of the hominids with their new hand and expanding brain.

As interesting as that story is, or might be to some of us, its importance extends well beyond the domain of historical and evolutionary conjecture. In fact, it has enormous implications for those of us who inherit the *Homo sapiens* hand-brain complex. The most important of these is that the hand is also a central focal point of individual human motor and cognitive development.

Each of us begins life primed to see the world, to learn from it, and to forge our own personal strategies for staying in and playing the game in rather particular ways. The human genome dictates that at the species level we are all the same, while at the individual level we are all different. How does this work? The British psychologist Henry Plotkin says it is done with what he has called "heuristics" — he means inherent, individually specific physical and mental capacities by which we tune into and react to important conditions or events in the environment. Plotkin uses the term "heuristic" — a word from classical Greek meaning a teaching device or strategy — because he wants us to understand that we are equipped not only to survive physiologically but also to *learn* how to survive behaviorally in the face of both certain and uncertain dangers. Our personal genetic heritage predisposes each of us to excel in the learning and perfection of certain kinds of survival skills more than we do at others, with the resulting diversity adding strength to organized human communities.

Since "heuristics" is an uncommonly stubborn word for most people to cozy up to, I should add this point: Plotkin uses it because he has an unusual and rather provocative notion of what "knowledge" is. Knowledge is *any* state in an organism that bears a relationship to the world. A bullfighter's knowledge is the sum of multiple integrations of joint angles and muscular attachments at the hip, in the spin and in the knees, ankles, and feet, all transformed into synergies of poised, fluid, and gracefully explosive movement. This knowledge also includes a thirst for adrenaline, a capacity for total concentration and — just in case the bull is unimpressed — the flawless chemistry of clotting factors and antibodies in the blood. The bullfighter's heuristic, in other words, provides for advanced preparedness not only of the hand and eye, but for a wide range of arousal and protective mechanisms reaching down to the cellular level. And the bullfighter who has been gored by a bull has knowledge that goes even deeper. Not only does he have the words *el toro* in his head and a memory and powerful emotions connected with that incident blended into (or "informing") his own internal "representation" of the animal, but has a scar on his chest wall, too. The scar also "represents" the bull — it is a registration *on and in the body* of the bullfighter, a permanent reference to and symbol of the bull and of the encounter with it, and (in Plotkin's extremely interesting way of looking at things) qualifies as part of this bullfighter's *knowledge* of the bull. All of this, by the way, is set out in Plotkin's highly original book — it is a major treatise, really — *Darwin Machines and the Nature of Knowledge.*

What does it really matter to us how our brain became what it is? Well, if Plotkin is right, and because of what the anthropologist Kathleen Gibson has called the permanent immaturity of the human brain, we have a lifelong innate capacity to learn from our environment at least *some* things that could improve our own personal chances for survival. But no one can tell us what that capacity is, exactly. We have to find out for ourselves. How do we do that? How does anyone do that?

The general form of the answer is that we explore the world, we pay attention to our own reactions to it, and we make our natural affinities a guide to the efforts we make to improve ourselves. The best example I can think of to illustrate this principle is that of musicians. Musicians as a class make the *prima facie* case for the existence of a genetic blueprint for the self-discovery and voluntary pursuit of innate aptitude. Musicians are attracted at a very young age to musical activities, and if they decide to pursue music they find out for themselves what Henry Plotkin means by heuristics. They know instinctively that they will be good at music, they start developing their "chops" right away, and they understand the basics and can advance rapidly under their own guidance without having to be taught. Because our culture values high achievement in music and understands that the work on a musical career typically begins at an early age, no one, not parents, not the school, is inclined to interfere with the highly atypical and self-centered educational trajectory of the musical child

There is something else about heuristics when they are allowed to unfold in the developing child, and to mature in the adult. At one time, when I worked only with musicians, I thought that musicians invest their work with emotional importance simply because they are professional emoters — emotional about *everything.* But a more interesting possible explanation is that a lifetime of work developing the hands as the primary tool of self expression invests the hands themselves with unusual meaning, or with the power to give rise to intense feelings about particular activities or about others who are engaged in them. In fact it was that possibility that transformed the book I began writing 10 years ago into what it had become when it was first published. The list of people whom I interviewed included a great many non-musicians: there were jugglers, for example, and magicians, manual therapists and blacksmiths, surgeons, carpenters and car mechanics, about 30 people in all, both men and women.

The first such individual I met was a gentleman named Anton Bachleitner —I met him in 1989 while I was working at the University of Dusseldorf. Bachleitner is the director of the Dusseldorf Marionette Theater, is in his early 40's and has been involved with puppets for most of his life. It was he who alerted me to what I now recognize as a common experience of people whose lives revolve around what they do with their hands. He went to his first puppet show when he was 8 years old and knew instantly that he would spend the rest of his life with puppets. What kind of fluke was this?

The Canadian educator Kieran Egan argues in his new book, The *Educated Mind,* that every child will experience a dawn of romantic awaking — a period when the child becomes infatuated with heroes and heroines, with great accomplishments, with epic history, and with the *Guinness Book of Records.* This is the first swell of the rising tide of adult consciousness and ambition. It is pure *eros* in the imagination of life's possibilities, and it has all the energy of burgeoning sexuality. Children, sometimes even before the age of 10 years, can see an adult doing something that not only excites them but completely engulfs them with the desire to do the same thing, or to emulate that adult. For Bachleitner it was puppets and it began when he was 8 years old. For Serge Percelley, a juggler whom I met when he was performing with the Big Apple Circus in New York, and both of whose parents were Belgian circus performers, it happened when he was 14 and for the first time had been allowed to travel with his parents when they left home on a circus trip:

> I saw one of these jugglers and I was just fascinated — *amazed* — by it, and knew it was something I wanted to do. I was not only watching, I was really hypnotized — it wouldn't go out of my head. I didn't know if I had the talent, but after seeing him, before even trying, I already knew that was what I wanted to do. I knew that without knowing if I *could* do it or not. I didn't even wait to buy balls — I started with stones. It was so fast. I've been caught in it from that day until now.

I have heard many versions of this same story, sometimes as a hazy memory, and I have heard it enough to make me believe it must be an elemental drive toward adult knowledge and standing beginning in the pre-adolescent years. And there doesn't seem any way to predict what exactly will trigger it, any more than there is any way to predict who a child's first crush will be. But as I suggested in *The Hand:*

> When personal discovery and desire prompt anyone to learn to do something well with the hands, an extremely complicated process is initiated that endows work with a powerful emotional charge. People are changed, significantly and irreversibly it seems, when movement, thought, and feeling fuse during the active, long term pursuit of personal goals.

Let me put that a slightly different way: if the hand and brain learn to speak to each other intimately and harmoniously, something that humans seem to prize greatly, which we call autonomy, begins to take shape.

Percelley also tipped me off about something else which has always been something of mystery to cognitive science. After we had spent some time discussing how he taught himself to be a skilled performer, I asked him where the ideas for his acts come from. His answer now seems to me far more significant than either of us thought during our conversation:

> Nobody really *invented* juggling and most of it just comes around by practicing. But as you do it more, you get the little ideas that just come with the practicing. When you practice seven hours a day, like I used to, you get to a certain stare of mind where you just do whatever goes through your head. You just try anything. You don't really care what goes where — you just *try* things — you experiment.

What he was telling me, I have come to realize, is that the curious, exploratory, improvisational interaction of the hand with objects in the real world gives rise to what we call "ideas." This process begins quite early in the child, and is usually described in somewhat mechanical terms, usually as an essential stage in sensorimotor development or in hand-eye coordination. Not many people think of the pre-verbal child as having ideas as such, but that is because most people think of ideas as being constrained by the operations of formal language. Ideas, in fact, are more intimately related in development with the interaction of the body with the world, and for humans, beginning at around the age of one, the possibilities for such interaction begin to explode. Control over movement of individual digits begins, and as the baby's bottom removes itself from the floor, the range of objects that can be encountered and tested rises just as dramatically. This, of course, is the age at which rudimentary language begins.
At this point I would like to say something specifically about the contribution of genetics to human learning. Plotkin argues that genetics can equip us to cope with life only to the extent that life itself satisfies certain premises about the state of the world contained in the genetic code for our species. For example, the human genome specifies that about 50% of the muscle mass of humans is located in the legs; for chimps, it's a little less than 40%, which makes sense because humans rely almost entirely on the legs for locomotion, whereas chimps use their arms both for walking and moving through the trees. But the human genetic code says very little about how we will use our legs to walk — we can go barefoot, or we can put on shoes, or roller blades, or even skis, or travel by bicycle, if we are willing to take the trouble to learn by imitating others who already know how to do those things, or by having them teach us.

The primary heuristic encodes for muscle mass, for the cadences of upright walking, and for a variety of common gait patterns because the force of gravity is very stable over enormously long spans of time. Through experience and training we gradually acquire secondary heuristics, which are the learned higher level motor and cognitive skills that allow us to improve on simple walking, or to operate whatever special devices we may have created for that purpose. Happily for us, probably because life was almost nothing *but* uncertain futures for the earliest hominids, our own brains have room to appropriate information about present context and the capacity to calibrate our perceptual-motor abilities as we grow. This is why we remain mentally immature for most of our lives, and it is also why we follow the ancient primate plan for instructing our young. Although our genetic code does not tell us what skills we must teach our children, it does make parents instinctive teachers and makes the young instinctively curious and experimental. Evolution seems to have made the hand a sort of express lane for secondary heuristics in humans, the primary channel through which the brain tunes itself to the particular world in which the child finds herself or himself from the moment of birth.

Children learn by being brought up in the company of parents, other adults, sibs and other children, from the toys they are given and the games they are taught to play, and from the behavior of an infinite variety of objects grasped and manipulated in their hands. They already understand how to learn from others, and how to teach themselves, by the time they reach school age, but schools can change the learning process for children in profound ways. Most of these are positive, but there are dangers as well; for example, the process can easily be divorced from family and community life, or the school can substitute an approved list of adult career goals for the child's native curiosity as a prime mover behind his or her personal search for skill mastery and understanding.

There is no doubt that formally organized human education systems are remarkably good at accomplishing what they are usually intended to do, which is getting kids preprogrammed for success in the societies in which they are raised. And even though mistakes are made, because not even a perfect human plan for education could be perfectly executed, the randomness of the failures and deficiencies is a protection (as it always is in Darwinian systems). Sometimes what looks like a mistake or a failure turns out later not to have been, just as in all of biology.

But suppose that a bad idea were to be suddenly injected into the educational system in a narrow but massive way all at once, before anyone has any way of knowing just how bad that idea is because its negative effects will not be discovered until 30 years later. We have a perfect example of such a situation in medicine: when pure oxygen became widely available for medical use, it was popular to treat the respiratory distress of premature infants with inhaled oxygen. It was not until 20 years later that virtually all of these children became blind because of the development of cataracts. Is it possible that a mistake of this magnitude could be made in education? I think it is. Suppose, for example, that it turns our that kids are like free-range chickens with respect to early childhood hands-on experiences. It doesn't really matter precisely what they pick up and tinker with, or pull apart and try to put back together, but they actually need to do *something* of that kind or else they will turn out later to be incapable of grasping nor just a screwdriver or a wrench but an *idea* that comes easily when you can remember what such a tool feels like or behaves in your hand, and doesn't come to you at all if you have never had your hands on anything but a computer keyboard or a mouse or a joystick.

Recently, under enormous pressure from the business community (and from parents who worry about the economic future of their children) schools have begun systematically and rapidly to eliminate a whole class of young children's physical interactions with real objects in the real world, and to replace them with visually-mediated simulations of those experiences. The Internet is proclaimed with something like a manic fever as being an essential element in early childhood education, because (as the argument goes) they need as much information as they can get. Do we know what the result will be? Where is the research that tells us this is the right course of action? Are there risks we cannot yet see? Is it possible that we could for the first time in history produce a whole generation of kids who are — how to say this — perceptually recalibrated or imaginatively diverted in some unforeseen way?

Not to be perverse, but it may be that what children need is not more information, but *less.* Stephen Talbott, who wrote a book called *The Future Does Not Compute,* was another of the faculty at the conference in late 1997 at Columbia Teachers' College. I'd like to quote briefly from his remarks there.

> Those of you who have read some of Tom Brown's books will know that Stalking Wolf, the old Apache Scout, had a peculiar way of teaching his young students during their ten-year partnership. Stalking Wolf was no citizen of the Age of Information, for his "coyote method" of teaching came close to a flat-out refusal to divulge information. In response to questions, he would say things like, "Go ask the mice," or "Feed the birds." The student would immediately be off on a new adventure of days' or weeks' duration. To teach fire-making with a bow drill, Stalking Wolf gave Tom a piece of oak from which it would have been impossible to coax a live coal. Only much later, and after long struggle, did Tom discover that, using cedar wood, he could start a fire almost instantly, thanks to the techniques he had honed so well upon the recalcitrant oak. So now, not only did he know how to make a fire, but, much more importantly, he had a good start at understanding the qualities of different woods. His particular skills grew out of an understanding of the world in which he was embedded, and therefore were readily refined and extended.

It seems to me that contemporary cognitive science began a backward slide into a deep state of confusion at about the same time biologists stopped doing what Darwin and countless other biologists had been doing since 1758 when the Swedish naturalist Carolus Linnaeus revised the science of taxonomy: collecting, holding, even living with live animals, and dissecting and drawing them. In place of all this manual interacting, biologists began *computerizing* their observations, their analyses, and finally even computerizing their *imagery.* By the latter, I am not referring to the use of computers to generate diagrams and images, but to a change in the way scientists began to think. I mean that scientists' images of brains began to merge with and to reflect their fantasies about computers.

The legendary father of Artificial Intelligence, Alan Turing, proved that a simple machine could be programmed to perform logical operations and he postulated that such a machine might even eventually be able to "think." Turing could easily be a demon in my story, but I think this would be deeply unfair to him. At least as portrayed in John Casti's wonderful new book, *The Cambridge Quintet,* Turing was just as interested as the famous Russian psychologist Nicolai Bernstein in the relationship between computation and movement, and in fact argued that the ideal thinking machine would move and would be equipped with all of the sensory capacities available to humans.

Unlike Turing, however, the cognitive world has come to see thinking and movement as separable, and the computational problem became the star attraction. So, whereas Turing wondered whether a computer could ever mimic human intelligence, at least some cognitive scientists — and I'm afraid, some educators — now wonder out loud if children can ever become as smart as computers. The flaw in this scare story is the same one made by anthropologists in the early part of this century, who thought that intelligence is simply a matter of the size of the computer (this is literally true: until the middle of this century it was widely held that the only difference between the earliest *Homo* brain and its predecessors was size, the dividing line between the australopithecines and *Homo* being drawn at 750 cc). No wonder some people believe that the optimal strategy for education is to seat one computer ready for data transfer — the child, that is — in front of another computer and to execute the download command.

Of course, there is nothing new about the educational fantasy behind our headlong rush to "wire" the classroom in order to intensify the child's exposure to whatever information is available on the Internet. Paulo Friere, in *Pedagogy of the Oppressed,* cut straight through to the heart of this idea when he said:

> The teacher's task is to organize a process which already occurs spontaneously, to *"fill"* the students by making deposits of information which he or she considers to constitute true knowledge... The banking concept of education is based on a mechanistic, static, spatialized view of consciousness and it transforms students into receiving objects.

And, just as with *real* banking, computers —and the Internet — are an ideal way to get around the inherent expense, messiness, and unpredictability of face-to-face, live, human interaction. This technology affords the opportunity to realize a level of control over the process entirely unimagined just a few years ago. The "banking" theory of education is not at all new, and perhaps it is not all bad, either. But the delivery system now available to transform that theory into a prophecy *is* new and represents an experiment utterly without precedent in the history of education. We should not assume that the money and political pressure behind the drive to put this system in place stems from any intention to foster independent thought and action among children. To some and possibly to a *large* extent, this new era of collaboration between business and education has been underwritten by entrepreneurs who have learned their lesson from the tobacco industry. Once the Internet is in place in grammar schools, or even kindergartens, and once banner advertising and corporate control of Internet search engines are in place, the child is well on his or her way to becoming any company's dream come true, a customer for life.

Ed Miller has recently published a small but important article entitled "The Three M's of Our Totally Wired Future" in *Orion Magazine.* In it, he strikes an optimistic note about the technologic revolution — and danger — in education, citing the Teachers College meeting.

> A broad consensus emerged from this meeting of psychologists, physicists, historians, philosophers, and computer scientists — that we need to learn much more about technology's potential for impeding the healthy development of children, especially young children, before we plunge headlong into further investment in computers. Teachers are often seen as the stumbling block in efforts to digitize education. They are ridiculed as "technophobes" who resist progress and innovation. In fact, teachers know more about technology and its limitations than they are generally given credit for. Many of our most effective and knowledgeable teachers are skeptical about the usefulness of computers in schools, and with good reason. But they have learned that speaking out against the technofaith has become a kind of heresy. Here's my hope for the future that good teachers and their allies will find their voices. Already there are a few signs. The research community and some thoughtful journalists are beginning to take seriously what teachers have known for a long time: that they can never replace the "human dimension" — the teacher's voice telling stories that feed the child's imagination; thc teacher's helping hand helping the child to grasp the butterfly net; the teacher's eye and heart that see, as no machine will ever see, the spark of recognition in the child's face.

I cannot say how much of Miller's cautious optimism I share, but I have my own hope:
that more teachers will credit the authority of biology in the design of formal learning situations provided to children. It seems abundantly clear to me that, because of the process of co-evolution, the hand enjoys a privileged status in the learning process, being not only a catalyst but an experiential focal point for the organization of the young child's perceptual, motor, cognitive, and creative world. It seems equally clear that as the child comes to the end of the pre-adolescent stage of development, the hand readily becomes a connecting link between self and community and a powerful enabler of the growing child's determination to acquire adult skills, responsibility, and recognition. This happens because of the hand's unique contribution to experiences which associate personal effort with skill mastery and the achievement of difficult and valued outcomes.
And I have one additional hope. Working teachers are our society's richest repository of experience and understanding about the needs and the potentials of children as learners. 1 hope they will credit their own authority and will make themselves heard in the ongoing debate about technology in education — if they do not, we and our children are in unprecedented danger.

The Real Meaning of "Hands-On" Education,

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