Deep Ecology: Educational Possibilities for the Twenty-First Century

by Fritjof Capra

Fritjof Capra's two-part lecture presents the fundamentals of systems thinking and sustainability along with the power of an ecologically comprehensive theory to shape education to fit the needs of human development in relation to the environment. Dr. Capra aims for the big picture emphasizing that effective learning is a system embedded in the web of life, which is yet another system. It gives us the ability to see the interconnectedness of the environment, of the community, of the natural world all at once—"a network of phenomena that are fundamentally interconnected." Capra maintains that systems theory, including systems learning, is a new way of seeing the world as living connections in which humans are playing their part in finding a real sense of belonging by working in direct contact with the natural world and all of its facets.

Part 1

Good morning. It's a pleasure to be here and to have this opportunity of an exchange of ideas with you. What I'm going to say will be based on my last two books, *The Web of Life* and the just recently published book *The Hidden Connections.*

In the last chapter of *The Hidden Connections,* I talk about what political scientists now are beginning to call a global civil society—that is, a global network of nongovernmental organizations that opposes the current form of economic globalization and has alternative ideas of how to build a global economy with humane values and ecological sustainability integrated into it. This is a vast movement, and they have organized not only numerous protest actions, beginning with Seattle in 1999, but also what they call a World Social Forum in Brazil every year. This January will be the third World Social Forum, and I'm very honored to have been invited to speak there. It will involve fifty thousand people who are activists—peace activists, environmental activists, people concerned with the shape of globalization, representatives from the labor movement, many representatives from the southern hemisphere, and so on.

This is a huge worldwide movement, of which I have been part, now, for the last few years. When I go to discussion groups or when we have strategy sessions, again and again I meet people who say that they went to either a Montessori school or a Waldorf school, about in equal proportions. So what you're doing, indeed, has a huge influence, and it is in the character of nonlinear systems (about which I've written a great deal lately) that we cannot predict consequences of our actions because things travel around and there are feedback loops and there are all kinds of non-linear pathways. That's why I chose this title *The Hidden Connections,* because we don't know all the connections. But you can rest assured that what you're doing is extremely valuable and will have these larger social and political effects.

With that, let me begin to talk about the topic "Deep Ecology: Educational Possibilities for the Twenty-First Century." This presentation will be structured in two parts: In the first part I will speak about various facets of ecology and sustainability, and then in the second part about implications for education.

Now when we talk about educational possibilities for the twenty-first century, we are looking at the big picture, at years and decades ahead. This means that we have to look beyond current policies, beyond the current state of the economy, current problems of schools, professional development, college admission policies, and so on—all the things that we deal with in our day-to-day work as educators. But let's look beyond all that and let's look at the big picture. As our new century unfolds, one of the greatest challenges that we are facing is to build and nurture sustainable communities. I want to begin by discussing the concept of ecological sustainability because there has been a lot of confusion around this concept, even within the environmental movement.

The idea of sustainability was introduced in the early 1980s by Lester Brown, the founder of the Worldwatch Institute, who defined a sustainable society or community as one that is able to satisfy its needs without diminishing the chances of future generations. In 1987, the Brundtland Report of the United Nations used the same definition to present the notion of sustainable development, which since then has been very widely used. In the Brundtland Report, we read, "Humankind has the ability to achieve sustainable development to meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 2). It's the same idea that Lester Brown introduced. These definitions of sustainability are important moral exhortations. They remind us of our responsibility to pass on to our children and grandchildren a world with as many opportunities as the ones we inherited.

However, when you look at it, this definition of sustainability does not tell us anything about how to go about it. How do we actually build a sustainable world? How do we build a sustainable community? So I think what we need is an operational definition of ecological sustainability, one that gives us a clue of what it's all about and how we go about it. The key to such an operational definition is the realization that we do not need to invent sustainable human communities from scratch but can model them after nature's ecosystems because nature's ecosystems are, in fact, sustainable communities. Ecologists use the term *community* as a technical term. In scientific ecology, ecosystems are communities. They are communities of plants, animals, and microorganisms, and their outstanding characteristic—in fact, the outstanding characteristic of the whole biosphere—is their inherent ability to sustain life.

Therefore a sustainable human community must be designed in such a way that its ways of life, its businesses, its economy, its physical structures, its social institutions do not interfere with this ability of nature to sustain life. This is the key point: We should not interfere with nature's inherent ability to sustain life. This definition of sustainability is operational because it implies that the first step in our endeavor to build sustainable communities naturally must be to understand how nature does it, that is, to understand the principles of organization that ecosystems have developed to sustain the web of life. This understanding is what I call *ecological literacy.*

In the coming decades, the survival of humanity will depend on our ecological literacy, on our ability to understand the basic principles of ecology and to live accordingly. So this is the main theme that I'm going to explore with you here. Ecology has many facets. You can study ecology as a science or as a philosophy, there's a politics of ecology, there are technologies that are ecologically oriented, and so on.

Ecology, as you may know, is derived from the Greek work *oikos,* which means "household." So ecology is the study of how the Earth household works. More precisely, it is the study of the relationships that interlink all members of the Earth household. It can be pursued as a scientific discipline or as a philosophy. As a philosophy, it is known as Deep Ecology, and this is a philosophical school founded by a Norwegian philosopher, Arne Naess.

Arne Naess was a very well-established and well known philosopher before he turned to ecology. He is an expert in Spinoza and published voluminous books about various philosophical issues, and then turned to ecology and made a critical distinction between shallow and deep ecology. Shallow ecology, he said, is anthropocentric. It views humans as somehow above or outside of nature. It sees humans as the source of all value and ascribes only instrumental or use value to nature. So a redwood tree, for instance, is valuable because it can give us timber. That's the only value shallow ecology has for natural living systems, so it leads to an attitude of how to manage the environment for human purposes. Deep Ecology does not separate humans from the natural environment, nor does it separate anything else from it. It does not see the world as a collection of isolated objects but rather as a network of phenomena that are fundamentally interconnected. Deep Ecology recognizes the intrinsic value of all living beings and views humans as just one particular strand in the web of life. It recognizes that we are all embedded in and dependent upon the cyclical processes of nature.

When you think about it, you will see very soon that, ultimately, deep ecological awareness is spiritual or religious awareness. So Deep Ecology as a philosophy is a link between science and spirituality. Why? Well, when the concept of the human spirit is understood as a mode of awareness, a mode of consciousness in which the individual feels connected to the cosmos as a whole, it becomes clear that ecological awareness, which is the awareness of connectedness—of being embedded in nature—is spiritual in its deepest essence. So it is not surprising that Deep Ecology is consistent with the so-called Perennial Philosophy of various spiritual traditions, whether we talk about the spirituality of Christian mystics or Islamic mystics, that of Buddhists, or about the philosophy and cosmology underlying the American Indian traditions. All these have common characteristics that are also characteristics of Deep Ecology.

Let me now turn to science. In science the most appropriate framework for ecology is the theory

Courtesy of Liz Ammond, The Children's House, Traverse City, Michigan of living systems. This is a theory that is only now fully emerging but has its roots in several fields of study that were developed during the first half of the twentieth century. Organismic biology, for instance, which concentrates on the organism as a whole, is a branch of biology that originated in the 1920s and 1930s. At the same time, there was the rise of Gestalt psychology, a psychology seeing perception as the perception of patterns, of forms. The German word for "living form" is *Gestalt.* German is my native language, so it's interesting for me to consider that we have two words for *form* in German. One is the same as the English *form* and the other one is *Gestalt. Gestalt* is a living form—a living body has a *Gestalt.* So psychologists adopted that and it was transferred into English in the term Gestalt psychology. Then there was general systems theory, and then cybernetics was more specifically a study of theories of living systems.

In all these fields, scientists explored living systems. In my book *The Web of Life,* I have a whole chapter about this history of systems theories in the early twentieth century. Scientists explored living systems, which means integrated wholes whose properties cannot be reduced to those of smaller parts. That was the key to systems theory, and it was formulated in the phrase that became sort of the banner of systems theory, "The whole is more than the sum of its parts."

Systems theory entails a new way of seeing the world and a new way of thinking, known as *systems thinking* or *systemic thinking.* It means thinking in terms of relationships, in terms of patterns, in terms of context. Systems thinking has been raised to a new level during the past twenty years or so with the development of complexity theory, which is a new mathematical theory, a new mathematical

Six-year-old using zoological charts that isolate distinguishing characteristics to do scientific classification, Japan language and a new set of concepts to describe the complexity of living systems.

Examples of these systems abound in nature. Every organism is a living system—that is, every animal, plant, microorganism, or human being. All these organisms are integrated, whole living systems. Parts of organisms are also living systems. For instance, a leaf or a cell are also living systems. So we see systems within systems—a nested order of systems nesting within systems. And then we have not only individual organisms and their parts but also communities of organisms, either in social systems—like a family, a school, or a village—or ecosystems, where different species live together.

All these living systems are wholes whose specific structures arise from the interactions and interdependence of their parts. Systems theory tells us that all living systems share a set of common properties and common principles of organization. This means that systems thinking can be applied to integrate academic disciplines and to discover similarities between different phenomena within the broad range of living systems. So you can talk, for example, about the *health* of a city, or you can talk about the *stress* of a community and compare it to the stress of an individual organism. Or you can talk about the *stress* of an economy and, again, you will be able to push these analogies quite far because these are all living systems that show similar phenomena.

Now let me go a little bit deeper into the nature of these living systems. One of the most important insights of the systemic understanding of life is the recognition that networks are the basic pattern of organization of all living systems. Wherever we look—for example, ecosystems are understood in terms of food webs, that is, networks of organisms that feed on one another. Then organisms are networks of cells and cells are networks of molecules. So the network is a pattern that is common to all life. Wherever we see life, we see networks.

Now, of course, not every network is a living system. A chicken wire fence is a network, a fishing net is a network, but obviously it's not alive. So what's the characteristic, or what are the characteristics, of a living network? Well, there's one key characteristic, and that is that living networks are self-generating. Let me take the example of a cell. In a cell, all the biological structures are continually produced, repaired, and regenerated by a network of chemical reactions. The cell, as you probably know, has a membrane that lets in the food, the simple molecules. It doesn't let in everything; it is semi-permeable. Certain things it lets in, other things it keeps out, and so it maintains the integrity of the cell. What comes in are simple food molecules: oxygen, sugars, and so on. And the cell, the network of chemical processes, produces all the larger molecules, the so-called macro-molecules: the proteins, the enzymes, the DNA, the cell membrane. All this is produced by a network of chemical processes. By the way, I've always felt that biology teachers neglect this perspective and teach the children simply to remember the various parts of the cell. Every school textbook of biology will have these pictures of a cell with these complicated names that the kids have to remember. And they will tell them, probably, what these various parts of the cell do, but they don't tell them how they are interconnected and how they are actually built and continually renewed, repaired, and rebuilt by a network of processes.

Well, similarly, at the level of a multi-cellular organism, the bodily cells are continually regenerated and recycled by the organism's metabolic network. So living networks continually create or recreate themselves by transforming or replacing their components.

Now we can transfer this knowledge to the social domain, and this is what I've done in my last book, *The Hidden Connections.* Life in the social realm can also be understood in terms of networks. But here we are not dealing with chemical reactions; we're dealing with processes of communication. So living networks in human communities are networks of communications. Like biological networks, they are self-generating, but what they generate is mostly nonmaterial. Each communication creates thoughts, and meaning creates information. And this gives rise to further communications. Just think of conversations, just think of, say, a conference like this—when you have lunch or dinner with people or have a drink in the bar and there's a conversation that reminds you of something you said to somebody else in the morning and that triggers a new idea and then sparks a new conversation, and so things go round and round. In this way the entire network of conversations or communications sustains itself. As this continues in a social network, these communications eventually produce a shared system of beliefs, of explanations, of values, a common context of meaning, which is known as *culture.* This is what we call culture, which is continually sustained by further communications. And through culture, individuals acquire identities as members of the social network.

In my last book, I go into considerable detail in comparing biological networks and social networks and analyzing the process of how culture is created and so on. I don't want to go into these details here. Let me just point out one aspect. It is important to realize that these living networks, both the biological networks and the social networks, are not material structures, like a spider's web, for instance. They are functional networks, that is, networks of relationships between various processes. In a cell, as I said before, these processes are chemical reactions between the cell's molecules. In a food web, the processes are processes of feeding, of organisms eating one another. In a social network, the processes are communications. And in all these cases, the network itself is a nonmaterial pattern of relationships. You cannot go out into a forest or a meadow and take a picture of a food web. You have to understand the processes, the relationships. This is why ecology is the study of relationships. Understanding living systems leads us to the understanding of relationships.

This shift of focus from objects to relationships is not an easy one because it is something that goes counter to the traditional, scientific enterprise in western culture. In science, as you know, we have been taught that we measure and weigh things. Some people even say what cannot be measured and weighed is not important or even what cannot be measured and weighed does not exist. So we have been trained, when we want to be scientific, to measure, to quantify. Relationships cannot be measured and weighed. You cannot put relationships on a scale. Relationships need to be mapped, so you draw a map of interconnections. You map it out, you see how different elements in a system or different members of a community are interrelated. And when you do this, when you engage in this mapping, you will discover certain configurations of relationships that appear again and again. This is what we call *patterns.* A pattern is a configuration of relationships. So the study of relationships leads us to this study of patterns.

Here we discover a tension that has been characteristic in Western science and philosophy throughout the ages: the tension between two approaches to the understanding of nature, which I call the study of matter and the study of form—form or pattern. These are two very different approaches. The study of matter begins with the question, "What is it made of?" This leads to the notions of fundamental elements, building blocks; it leads to measuring and quantifying. And this of course is very necessary to understand the natural world. The study of form asks, "What is the pattern?" That leads to the notions of order, organization, relationships. Instead of quantity, the study of form involves quality. Instead of measuring, it involves mapping. So these are two very different lines of investigation that have been in competition with one another throughout our scientific and philosophical tradition.

For most of the time in western science the study of matter, of quantities and constituents, has dominated. This is not true in eastern science. Just think of the difference between western and eastern medicine. When you are sick and go to a western doctor, typically the way of determining what's wrong with you is to take a blood sample and send it to the lab. They analyze it—that is, they determine the quantities of chemicals present in the blood. So it's a quantitative analysis, and they deduce from that some symptoms, some disease, which is defined in terms of those quantities. When you go to a traditional Chinese doctor, the situation is very different. He or she will take your pulse and, from a very complex way of taking several pulses on your hand, they will determine a pattern of relationships expressed in terms of meridians and the flow of chi. And then from that pattern of relationships, they will deduce strengths and weaknesses—you know, illness and health. So it's a very different approach. Both are scientific, but they're very different types of science.

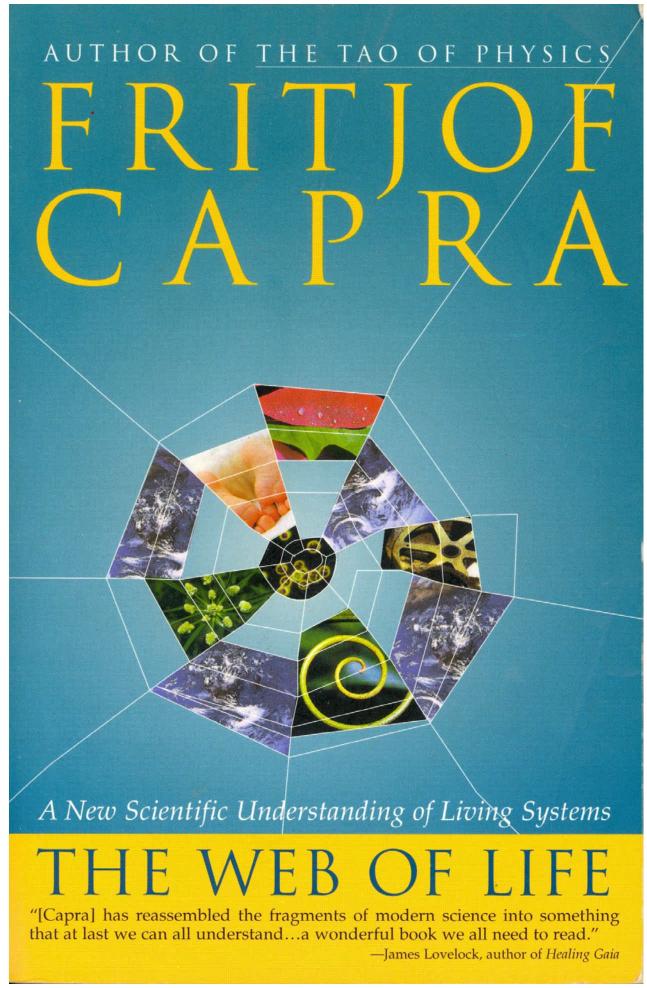
Now in the last decades, the rise of systems thinking has brought the study of patterns and relationships to the foreground again in western science. The main emphasis of complexity theory is on patterns. You may have heard of strange attractors in chaos theory or fractals in fractal geometry; these are all patterns that are generated mathematically. In fact, the whole new mathematics of complexity is essentially a mathematics of patterns.

Now, as I said before, understanding patterns requires visualizing and mapping. And here we see something very interesting. Every time the study of pattern has been in the forefront in western science, artists have contributed significantly to the scientific enterprise because a large part of the artistic approach is to visualize patterns. Perhaps the two most famous examples of artists who have contributed to science are Leonardo da Vinci in Renaissance Italy, whose whole scientific life was the study of pattern, and the German poet Goethe in the eighteenth century, who made significant contributions to biology through his study of pattern. I think this is important for us as educators because it opens possibilities of integrating the arts into the school curriculum. There's hardly anything more effective than the arts, whether it's the visual arts or music or the performing arts, for developing and refining a child's natural ability to recognize and express patterns.

So the arts can be a powerful tool for teaching systems thinking, in addition to other functions they have in education, in particular in addition to enhancing the emotional dimension that is increasingly being recognized as an essential component of the learning process. I'll come back to that in a few minutes.

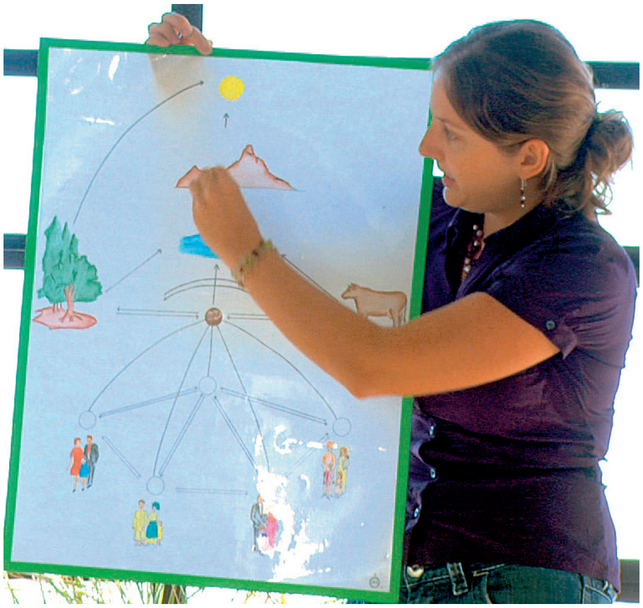
Now let me now return to the challenge of building sustainable communities. The first step on the road to sustainability is ecological literacy or *ecoliteracy*, that is, understanding the principles of organization that ecosystems have evolved to sustain the web of life. When systems thinking is applied to the study of the multiple relationships that interlink the members of the Earth household we can recognize a few basic principles. Those may be called principles of ecology or principles of sustainability or you might even call them the basic facts of life.

We need a curriculum that teaches our children these fundamental facts of life, for example, the fact that in an ecosystem one species' waste is another species' food; that matter cycles continually through the web of life; that the energy driving the ecological cycles flows from the sun; that diversity assures resilience; and last, but not least, the fact that life, from its beginning more than three billion years ago, took over the planet not by combat but by networking.



Ecoliteracy is the first step towards sustainability. The second step is to move from ecoliteracy to *ecodesign.* We need to apply our ecological knowledge to the fundamental redesign of our technologies and social institutions so as to bridge the current gap between human design and the sustainable systems of nature. Design, in the broadest sense, can be understood as the shaping of flows of energy and matter for human purposes. Ecodesign is a process in which our human purposes are carefully meshed with the larger patterns and flows in the natural world. So ecodesign principles reflect the principles of organization that nature has evolved to sustain the web of life.

To practice industrial design in such a context requires a fundamental shift in our attitude toward nature: a shift from finding out what we can extract from nature to finding out what we can learn from her. In recent years, there has been a dramatic rise in ecologically oriented design practices and projects, all of which are now well-documented. Again, in



Presenting the "interdependencies of life": animals, plants, land, water, air, energy, and humans, courtesy of Colegio Montessori de Tepoztlán, Cuernavaca, Morelos, Mexico

the last chapter of my last book I have an extensive discussion and documentation of these ecodesign projects. For example, I begin this discussion with the renaissance of organic farming that is now happening around the world. Another example would be the organization of different industries into ecological clusters in such a way that the waste of any one organization is a resource for the next, just as in an ecosystem the waste of one species is food for the next.

Ecodesigners speak of a shift from a product-oriented economy to a service and flow economy, and what they mean is that industrial raw materials and technical components would continually cycle between manufacturers and users so that instead of buying and owning a television set, for instance, you would lease the set and you would buy the service. The set would be the property of the manufacturer, who would have the obligation to take it back after its life of use, or when you want a new television set, and to recycle the components. This implies a dramatic change of attitude of manufacturers and design practices. The reason simply is that if I buy a television, my purpose is not to own a box of four thousand toxic chemicals. That's not why I buy it. I buy it to watch TV, right? So the toxic chemicals should be owned by the manufacturer. I just lease the service. The same would be true for this floor carpet, for instance, which would go back to the manufacturer, or for cars, bicycles, or whatever. This is a big movement that is now beginning.

Well, rather than going into all these details, let me just concentrate on one important ecodesign area, and that is energy. In a sustainable society, all human activities and industrial processes must be fueled by solar energy, as in the ecosystems in nature. Because of the critical role of carbon in global climate change, it is evident now that fossil fuels are unsustainable in the long run, and therefore the shift to a sustainable society centrally includes a shift from fossil fuels to solar power. Indeed, solar energy is the energy sector that has seen the fastest growth over the past decade. During the 1990s, the use of photovoltaic cells increased by about 17% every year.

And wind power has grown even more spectacularly. It increased by about 24% each year during the 1990s, and last year—2001—it increased by an astonishing 31%. Since 1995, wind power has increased nearly fivefold while coal declined by 8%. Wind power offers long-term price stability and energy independence. It's obvious that there will never be an OPEC for wind because you can find wind everywhere; it's not concentrated in various areas. The total generating capacity from wind is now twenty-three thousand megawatts, worldwide, which is enough to meet the residential electricity needs of some twenty-three million people. And over the next decade, Europe alone plans to add about three times that amount. You can look up the references I give in the book. There is a list of countries, including China and of course the United States, that plan to add massive amounts of wind power in the next few years. Wind power has reached a threshold where it is rapidly becoming economical.

Now in this hopeful solar scenario, over the past twenty years, there has always been a major stumbling block. I remember frustrating discussions for years and years when people would ask, "Well, how do we drive our buses, cars, and trucks?," or I would speak at a conference about solar power and they would say, "Well, that's all very nice, but you came here in an airplane, didn't you? And was that driven by solar power?" So the problem of having a liquid fuel that can be stored and used for our cars and buses and planes and trucks, until recently, was a major stumbling block. However, during the last few years, this problem has found a spectacular solution with the development of efficient hydrogen fuel cells that promise to inaugurate a new era in energy production, which is now often called the *hydrogen economy.*

A fuel cell is an electrochemical device that combines hydrogen with oxygen to produce electricity, water, and nothing else. It is completely nonpolluting, has no other side effects, and operates silently—and this makes hydrogen the ideal fuel. Several companies around the world are now racing to be the first to commercially produce residential fuel cell systems. You would have a fuel cell, say the size of a washing machine, in your basement for all your energy needs in the house. In the meantime, Iceland has launched a multi-million-dollar venture to create the world's first national hydrogen economy. To do so, Iceland will use its vast geothermal and hydroelectric resources to produce hydrogen from seawater just by splitting the oxygen and hydrogen in the water, and then use it first in buses and cars and then in its fishing fleet. The goal set by the Icelandic government is to complete the transition to hydrogen between 2030 and 2040.

Where do you get hydrogen from? Well, it's the most common element in the universe. At present, natural gas is the most common source of hydrogen. It's essentially methane, which is $CH_{4,}$ so you have four hydrogen atoms to one carbon atom. But it still has carbon, so it still pollutes and contributes to global warming. In the long run, separation from water with the help of solar energy, especially wind power, will be the cleanest and most effective way of producing hydrogen. And when that happens we will have created a truly sustainable system of energy generation. We will use solar energy to split water into hydrogen and oxygen and then use the hydrogen in the fuel cell to produce electricity, which has the by-product, again, of water—that is, the hydrogen recombines with the oxygen to produce water. So it's a complete and clean cycle. Now you may ask, why go through the trouble of splitting hydrogen from water to produce electricity and then create water again? Why not use solar energy to produce electricity directly? The answer is storage, because we need a fuel that can be stored, so hydrogen can be piped like natural gas or oil and can be stored in cars to drive.

This brings me to the other technology that is closely related to energy, and that's automobile technology. There has been a redesign of automobiles that is just beginning now, that may be the ecodesign branch with the most far-reaching industrial consequences. This involves what physicist Amory B. Lovins and his colleagues at the Rocky Mountain Institute call Hypercars, hybrid electric cars using aerodynamic design, ultralight materials, and efficient accessories. As you probably know, there are several hybrid electric cars on the road now. I bought a Toyota Prius about a month ago, and it gets between forty and fifty miles per gallon. The cars that are not yet out but exist as prototypes get even better mileage: about eighty miles per gallon. Such cars have been tested by General Motors, Ford, Daimler Chrysler, and various other companies. In fact, last week Toyota announced that within ten years all its cars will be hybrid electric cars. And that will, of course, influence the whole automobile industry dramatically.

Now, one thing connected with these new technologies is the realization that a massive investment in these Hypercars could easily make us completely independent of foreign oil. Just think what this would do to our foreign and military policies. In fact, and this is an important statistic to know, if we increased the fuel efficiency of our light vehicles—not the trucks and buses, only the light vehicles—by a mere 2.7 miles per gallon, we would not need to import any Persian Gulf oil. The current average gas mileage is around 20 to 22, and as I told you, the Prius gets about 40 to 45, so to increase the average by 2.7 miles per gallon, up from 22, is nothing; it could be done very easily.

We are talking here about the future of our children and future generations, and it behooves us to teach our students that we are now at the beginning of a historic transition from the petroleum age to the hydrogen age. Oil, as you know, is currently cheap in the United States, if you look only at the price we pay at the pump. But the military costs to protect each barrel of oil are actually higher than the price of the oil. The environmental costs are even higher and make the real price of oil prohibitively high. As the transition to the hydrogen economy progresses, its energy efficiency will become so superior to oil that even cheap oil eventually will be uncompetitive and thus no longer worth extracting.

I want to close this first part with one of my favorite statements from the ecodesigners: The Stone Age did not end because people ran out of stones. So the petroleum age will not end because we run out of petroleum. It will end because we have developed better technologies. The implications for all this—ecology, sustainability, and ecodesign—obviously are enormous. Let me stop here, and I will then go on to discuss this in the second part.

Part 2

In the first part of my presentation, I discussed the concepts of sustainability and Deep Ecology, the basic principles of ecology and systems thinking, and then I gave you a brief overview of a recent development in ecodesign. In this second part, I shall discuss the implications of all these ideas for education. I should tell you that I have some experience of Montessori education because my daughter went to a Montessori school from grade five to eight. She is now a junior in high school, but I still remember the Montessori years very well. However, I never studied Montessori pedagogy. So my experience is just as a parent being very involved in my daughter's education and knowing her teachers and occasionally sitting in on classes and looking at their exhibits and interactions.

Although I see a lot of connections of what I'm going to say to Montessori education, I'm not going to emphasize them. I'll leave that up to you. I'll be very curious to hear from you, then, in the discussion section, how you see this being related to the Montessori system.

Let me begin with ecoliteracy. In order to be able to build and nurture sustainable communities, we need to become ecologically literate. That is, we need to understand the basic principles of ecology and we need to learn how to embody them in the daily life of our human communities. Teaching this ecological knowledge, which by the way is also ancient wisdom, is the most important role of education, I feel, in this new century. Ecological literacy, or ecoliteracy, must become a critical skill for politicians, business leaders, and professionals in all spheres and should therefore be the core of education at all levels, from primary and secondary schools to colleges, universities, and the continuing education and training of professionals.

At the Center for Ecoliteracy in Berkeley, my colleagues and I are developing a system of education for sustainable living at the primary and secondary school levels. This involves a pedagogy that puts the understanding of life at its very center—an experience of learning in the real world that overcomes our alienation from nature and rekindles a sense of place, and a curriculum that teaches our children the basic principles of ecology. This ecoliteracy is now being taught within a growing network of schools in California and is beginning to spread to other parts of the United States and the world.

Similar efforts are underway in higher education, pioneered by an organization called Second Nature, located in Boston, which collaborates with numerous colleges and universities to make education for sustainability an integral part of campus life. I know some of you have heard David Orr speak, who is also on our board of directors at the Center for Ecoliteracy. David Orr directs the Center for Environmental Science at Oberlin College in Ohio, where he pioneered a building, an environmental science study center, that is the state of the art in the world in ecological design.

Let me now review the main components of ecoliteracy as we have developed them in Berkeley. I shall try to cover as many aspects as possible in this brief overview, but I want to emphasize that my words can only convey a small part of the story. I brought a few slides, and as always the real message is in the children's faces—their smiles, their stories, their poetry. I encourage you to go to our website, www.ecoliteracy.org, where you will find plenty more pictures, stories, and additional practical information.

Over the last ten years, we have found that growing a school garden and using it as a resource for cooking school meals is an ideal project for experiencing systems thinking and the principles of ecology in action, and for integrating the school curriculum. Gardening reconnects children to the fundamentals of food, indeed to the fundamentals of life, while integrating and enlivening virtually every activity that takes place at a school.

One of the key characteristics of living networks is the fact that all the nutrients are passed along in cycles. In an ecosystem, energy flows through the network while water, oxygen, carbon, and all the other nutrients move in these well-known ecological cycles. Similarly, the blood cycles through our body and so the air, the lymph fluid, and so on. Wherever we see life, we see networks, and wherever we see living networks, we see cycles. The web of life, the flow of energy, and the cycles of nature are exactly

Courtesy of Cornerstone Montessori School and Cornerstone Montessori Elementary School, St. Paul, Minnesota

the phenomena that are experienced, explored, and understood by children through gardening. The understanding of life in terms of networks, flows, and cycles is relatively new in science. But it is an essential part of the wisdom of spiritual traditions. And it is not a coincidence that gardening and preparing food from what grows in the garden have been integral parts of religious practices in many spiritual traditions. Gardening and cooking are examples of cyclical work, work that has to be done over and over again, work that does not leave any lasting traces. You cook a meal that is immediately eaten. You clean the dishes, but they soon will be dirty again. You plant, tend the garden, harvest, and then plant again. This work is part of monastic practice because it helps us recognize the natural order of growth and decay, of birth and death, and thus makes us aware of how we are all embedded in those cycles of nature.

In the garden, we learn about food cycles and we integrate the natural food cycles into our cycles of planting and growing, harvesting, composting, and recycling. Through this practice, we also learn that the garden as a whole is embedded in larger systems that are again living networks with their own cycles. The food cycles intersect with these larger cycles—the water cycle, the cycle of the seasons, and so on—all of which are links in the planetary web of life. In the garden, we learn that a fertile soil is a living soil, containing billions of living organisms in every cubic centimeter. These soil bacteria carry out various chemical transformations that are essential to sustain life on earth.

Because of the basic nature of the living soil, we need to preserve the integrity of the great ecological cycles in our practice of gardening and agriculture. This principle is embodied in traditional farming methods, which are based on a profound respect for life. Farmers used to plant different crops every year, rotating them so that the balance in the soil was preserved. No pesticides were needed since insects attracted to one crop would disappear with the next. Instead of using chemical fertilizers, farmers would enrich their field with manure, thus returning organic matter to the soil to re-enter the ecological cycles.

About four decades ago, this age-old practice of organic farming changed drastically with the massive introduction of chemical fertilizers and pesticides. Chemical farming has seriously disrupted the balance of our soil, and this has had severe impact on human health because any imbalance in the soil affects the food that grows in it and therefore the health of the people who eat the food. Fortunately, a growing number of farmers have now become aware of the hazards of chemical farming and are turning back to organic ecological methods. The school garden is the ideal place to teach the merits of organic farming to our children.

Through gardening we also become aware of how we ourselves are part of the web of life. And over time, the experience of ecology in nature give us a sense of place. We become aware of how we are embedded in an ecosystem, in a landscape with a particular flora and fauna, in a particular social system and culture, and this gives us the opportunity of integrating the school curriculum around the garden and food, drawing in history, other social sciences, and studies of culture.

Now, beyond that, being in the garden is something magical. It is something that is very special for children, especially young children. Let me quote here one of our teachers, who said the following at one of our recent meetings: "One of the most exciting things about the garden is that we are creating a magical childhood place for children who would not have such a place otherwise, who would not be in touch with the earth and the things that grow. You can teach all you want, but being out there, growing and cooking and eating, that's an ecology that touches the heart and will make it important to them." And I want to emphasize that this can be done in an urban environment. This is especially important for children in an urban environment, who would not have an opportunity otherwise to go out much into nature.

In the garden, we observe the life cycle of an organism, the cycle of birth, growth, maturation, decline, death, and new growth of the next generation. Through gardening we experience growth and development on a daily basis. Indeed, the understanding of growth and development is essential, as you well know, not only for gardening, but also for education. So the children learn that while their work in the school garden changes with the development and maturing of the plants, the teacher's methods of instruction and the entire discourse in the classroom changes with the development and maturing of the students.

Since the pioneering work of Maria Montessori, Rudolf Steiner, and Jean Piaget, a broad consensus has emerged among scientists and educators about the unfolding of cognitive functions in the growing child. Part of that consensus is the recognition that a rich, multi-sensory learning environment—that is, the shapes and textures, the colors, smells, and sounds of the real world—is essential for the full cognitive and emotional development of the child. Learning in the school garden is learning in the real world at its very best. It is beneficial for the development of the individual student and the school community, and it is also one of the best ways for

Courtesy of Chris Trostel, Montessori Borealis Public, Juneau, Alaska children to become ecologically literate and thus able to contribute to building a sustainable future.

One of our biggest school gardens is in the Berkeley Middle School, and it is called The Edible Schoolyard. We have a publication called *The Edible Schoolyard*, and it's a report about the details of how this garden was formed, interviews of the school principal, of various teachers, and pictures. Another of our publications is called *Ecoliteracy: Mapping the Terrain,* and that gives sort of the theoretical overview of the various facets as I have described them here, but in more detail. A third is called *Getting Started,* and it gives practical advice about how to start a school garden. You can order these from our web site, www.ecoliteracy.org.

Now let me turn from those practical things to make a few comments about the process of learning. You see, because of its intellectual grounding in systems thinking, ecoliteracy thinking is much more than environmental education. It offers a powerful framework for a systemic approach to school reform, which has been widely discussed among educators. I'm talking here especially about public schools, where school reform, as I'm sure you know, has been a very hot topic. When you look at these discussions of American school reform in public schools, you can see that a systemic approach to school reform is based essentially on two insights: a new understanding of the process of learning and a new understanding of community and leadership. Recent research in neuroscience and cognitive development has resulted in a new systemic understanding of the process of learning, based on the view of the brain as a complex, highly adaptive, self-organizing system. And in the publication *Ecoliteracy: Mapping the Terrain*, there is a chapter on this with references to various books.

Because of the fundamental interconnectedness of the brain, everything that happens to a child has both direct and indirect consequences. Body and mind or brain and mind deeply interact. For example, stress can weaken the immune system, while relaxation and laughter can strengthen it. Playing the piano or singing in a choir improves spatial reasoning. Reading enhances a student's ability to think abstractly. These connections have been studied extensively in recent years. And educators increasingly have become aware that all learning is complex and that in every encounter teachers are dealing with the entire system, that is, with the entire child, the whole child.

Now, as you well know, like all living systems, the brain grows and develops. It is now well understood that in the growing child, brain growth is accompanied by a corresponding development of cognitive functions. And, as you know, in the developing cerebral cortex, brain growth does not mean growth of new nerve cells but growth of a complex network of connections, of neural interconnections. As the child matures, infinite possibilities for interconnections exist in this growing and developing neural network. Which connections actually form and which pathways and functions become stable depends very much on the child's environment. The neural network displays the important ability to alter its connectivity in response to the environment, something that neuroscientists call *neural plasticity.* This sensitivity of the brain to environmental influences is especially strong in early childhood when most of the neural network is forming. Since research in this area began in the late 1950s, there has been a broad consensus among child psychologists that early exposure to an environment rich in sensory experiences and cognitive challenges will have lasting beneficial effects, while early deprivations will inhibit future neural development.

At the Center for Ecoliteracy we believe that learning in the school garden, in the kitchen, on the farm, or in the creek is learning in the real world at its very best. Now since the neural network alters its connectivity continually in response to the child's environment, this means that different children will develop different nervous systems because they grow up in different environments. So there will be different pathways, a different mix of cognitive functions. In other words, every brain is uniquely organized and therefore children display a great diversity of learning styles, involving, as Howard Gardner called it, multiple intelligences.

Another important implication of the view of the brain as an integrated whole embedded in larger wholes is the insight that learning involves not only the brain and the nervous system but the body's entire physiology, and, in particular, it turns out, the emotions are critical. Now in education, emotions have long been treated as important but as basically separate from thinking. Recent scientific discoveries, especially the research by Antonio Damasio, which I highly recommend, have forced us to change this view dramatically. Scientists have come to realize that emotion and cognition interact continually, energizing and shaping each other. What we learn, therefore, is not only influenced by emotions but is even organized by emotions. And this means, of course, that an emotionally safe learning environment is crucial to learning.

From the integration of cognition and emotion, let me now move to the fact that the child in the classroom is always embedded in a larger social environment, a social system. This is another insight of recent research into cognitive development and learning, that all learning is fundamentally social. Part of our identity depends on establishing community and finding ways to belong, and much of our learning depends on the communities of which we are part. And it is also a fact that learning is a fundamental property of all living organisms. All living organisms, all living systems are learning systems. So the challenge is not to stimulate the child to learn—the child will learn no matter what. Children always learn, and they learn from their communities. The questions are: Which communities do they choose to learn from and how can we shape and direct the learning? But they will always learn. You will find that children, teenagers, say, who have poor knowledge, say, in algebra or in chemistry, when it comes to pop songs they will know the lyrics of fifty, sixty songs. They will know the scripts of entire movies or episodes of *Friends* on television. They know it all by heart, they learned it all. So children always learn. The question is: What do they learn? So building healthy and intelligent communities is not only necessary for ecological sustainability but will also facilitate learning. And therefore since ecoliteracy is closely related to community building, it will provide a healthy and conducive learning environment.

Now in this very brief overview of recent brain research and its implications for learning, I've so far concentrated on the conditions that facilitate learning: a rich sensory environment, emotional safety, a supportive community. Now let me turn to the learning process itself. It is now well known that children do not come to school as empty vessels to be filled with information, but actively construct their knowledge by relating all new information to past experience in a constant search for meaning. From an evolutionary perspective, the search for meaning is survival-oriented and basic to human nature. We are innately motivated to make sense of our experience, to search for meaning. In fact, neuroscientists can show you that the brain resists having isolated pieces of information imposed on it. It will always make connections, establish patterns, and search for meaning.

How does the brain search for meaning? Well, I've come to understand meaning as the experience of context—that's my sort of definition of meaning, the experience of context. And context is a pattern of relationships between the thing or event under question and its environment. So the search for meaning is always a search for patterns. And indeed, this is what brain research tells us. The search for meaning occurs through *patterning,* as neuroscientists put it. This patterning is inherent in the physiology of the brain. Groups of brain cells combine to form cell assemblies and neuronetworks that fire in synchrony. New experiences and understandings reconfigure these automatic patterns. Learning is required when an entrenched pattern is challenged or disrupted. And one reason why such relearning often takes time is the fact that the changes are not just mental but also physiological. In fact, the two cannot be separated.

In their detailed analysis of patterning, neuroscientists have discovered that emotions are critical to this process. To me, this is one of the more fascinating results of these recent studies. They have found that when there is a lack of emotional security—when there is stress and the system is flooded with stress hormones—the perception of patterns is one of the first things that is lost. So if a child is under stress, the brain shuts down the ability to perceive patterns. The perception narrows down to concrete objects, so there's fragmentation, there's a shift from the whole to the parts. And this shows, once more, that emotional security is critical for the very essence of the learning process, the search for patterns and meaning.

Now it is obvious that the new understanding of the learning process suggests corresponding instructional strategies. In particular, it suggests designing an integrated curriculum emphasizing contextual knowledge in which the various subject areas are perceived as resources in service of a central focus or theme. An ideal way to achieve such integration is the approach that has recently been called *project-based learning,* which consists in facilitating learning experiences that engage students in complex, real-world projects through which they develop and apply skills and knowledge. In our ecoliteracy schools we practice project-based learning with either a school garden or a creek restoration project as the central focus.

Let me just tell you one story of how this can be used to integrate the curriculum. About ten years ago, when we began this ecoliteracy work, we came across a fourth grade class in a school north of San Francisco where the teacher was a passionate ecologist who told the kids about endangered species. The students decided, by themselves, they wanted to adopt a species and preserve it from extinction. So the teacher invited a member of the Audubon Society, a naturalist, into the classroom to talk about endangered species in the area. And the kids voted to choose a small shrimp called the California freshwater shrimp, which occurred in the creeks surrounding the school in that region, and they said we want to preserve this freshwater shrimp. So how did they do it? Well, the teacher told them, first you have to find out about the shrimp. So, in came the biology class, where they learned not only about shrimp but also about habitats, food webs, about the ecological region and the ecosystem. Then very soon they moved on to geography and drawing maps of creeks and learning where the school is situated, where the village or the town is situated, and so on. They found that the reason why the shrimp was endangered was that these creeks run through farmland where there is cattle farming. There used to be willow trees around the creeks, but they were not there anymore, and the cattle were trampling down the earth on the banks of the creeks when they drank the water, and that muddied the creeks so that the shrimp could not survive.

Japanese student

So the kids studied all that and they said well, we'll have to build fences and we'll have to plant willows and we'll have to get the farmers to do that. They also said, let's write to the city council. And the teacher told them, well, if you write to the city council you better make sure that the letter is well written, because otherwise they won't read it. So in came writing, spelling, all of that. They also got their education in civics, to learn about the city council, how that functions, the relationship of the farmers to the city council, and so on. So the entire curriculum was organized around saving the shrimp.

This was ten years ago, and then the Center for Ecoliteracy came in later and gave them successive grants. Now this has grown into a project we call STRAW, which stands for Students and Teachers Restoring a Watershed. About forty to sixty schools are involved in it in northern California. They planted willows along the creeks. The willows that were planted ten years ago are now eight to ten feet high, and the kids, of course, are now in high school and college, and they come back occasionally to look at the willows, to talk to the younger kids. And just in the last year, they discovered that the shrimp is actually coming back. So it's a huge success and it shows how the entire curriculum can be organized around a single focus. In our publication *Ecoliteracy: Mapping the Terrain*, we describe this example of how the kids saved the shrimp.

Well, it is obvious that this kind of approach, integrating the curriculum through gardening or any other ecologically oriented project, creek studies or whatever, is possible only if the school itself becomes a true learning community. One of the first lessons we learned, when we tried to help teachers design integrated school curricula, was that the history teacher doesn't talk to the science teacher and the science teacher doesn't talk to the English teacher. So the first few years, the first five years of our work was spent mainly in building community. We took teachers out of the schools into weekend retreats, and we took them through all kinds of experiences and exercises, and community building was the main part. In such a learning community, the focus is on learning and everyone in the system is both a teacher and a learner. There is a continuous, cyclical exchange of information. Feedback loops are intrinsic to the learning process, and systems thinking is crucial to understanding the functioning of these learning communities. Indeed, when you look at the principles of ecology in detail—networks, diversity, cycles, partnership, and so on—you can interpret them also as principles of community. Ecology and community go hand in hand.

To wrap this up, let me just summarize the basic components of ecoliteracy that I reviewed for you. The first is the understanding of the principles of ecology, experiencing them in nature and thereby acquiring a sense of place—the ecological dimension. The second dimension is incorporating the insights from the new understanding of learning that emphasizes the child's search for patterns and meaning. The third component is implementing the principles of ecology to build and nurture a learning community. And the fourth is integrating the curriculum in this community through project-based learning.

References

Ecoliteracy: Mapping the Terrain. Berkeley, CA: Learning in the Real World, 2000.

The Edible Schoolyard. Berkeley, CA: Learning in the Real World, 1999.

Getting Started: A Guide for Creating School Gardens as Outdoor Classrooms. Berkeley, CA: Center for Ecoliteracy, 1997.

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