

Ecology, Systems Thinking and Project-Based Learning

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One of the foremost signs of present-day industrial society is the presence of massively complex systems that increasingly permeate almost every aspect of our lives. We are surrounded by complexities that were difficult to imagine only half a century ago — global trading and broadcast systems, giant multinational organizations, automated factories, global markets, and so on.

The awe we feel in contemplating these wonders of industrial technology is tinged by a sense of uneasiness, if not outright discomfort. Although these complex systems continue to be hailed for their increasing sophistication, it is becoming ever more apparent that they are also the main driving force of global environmental destruction, and thus the main threat to the long-term survival of humanity. To build a sustainable society for our children and future generations — the great challenge of our time — we need to fundamentally redesign many of our technologies and social institutions so as to bridge the wide gap between human design and the ecologically sustainable systems of nature.

In this endeavor of redesigning our technologies and social institutions, the first step, necessarily, has to be the understanding of sustainability in nature. In other words, we need to understand how the ecological communities of nature, the ecosystems, organize themselves so as to maximize their sustainability. We need to become ecologically literate.

The mission of the Center for Ecoliteracy in Berkeley is to foster ecological literacy in K-12 education. Being ecologically literate, or “ecoliterate,” means, in our view, understanding the basic principles of organization of ecological communities (i.e. ecosystems) and using those principles for creating sustainable human communities. In particular, we believe that the principles of ecology should be the guiding principles for creating sustainable learning communities. In other words, ecoliteracy offers an ecological framework for educational reform.

Let me now give you a brief overview over the most important components of this framework of ecoliteracy; and to do so, let me begin with ecology.

The word “ecology,” as you may know, comes from the Greek *oikos* (“household”). Ecology is the study of how the Earth Household works.

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More precisely, it is the study of the relationships that interlink all members of the Earth Household. As John Muir, our famous naturalist, put it at the turn of the century,

*When we try to pick out anything by itself,
we find it hitched to everything else in the universe.*

LIVING SYSTEMS

The understanding of the relationships that interlink all members of the Earth Household is ancient wisdom: "We did not weave the web of life," says Chief Seattle, "we are merely a strand in it. Whatever we do to the web, we do to ourselves." And in ancient China, the Taoist sage Huai Nan Tzu wrote: "Those who follow the natural order flow in the current of the Tao." Both of these celebrated quotes express the very essence of ecoliteracy.

From this ancient wisdom, let me now turn to modern science, which is my own background. The most appropriate scientific framework for ecology is the theory of living systems. This theory is only now fully emerging but has its roots in several scientific fields that were developed during the first half of the century—organismic biology, gestalt psychology, ecology, general system theory, and cybernetics.

In all these fields scientists explored living systems, which means integrated wholes whose properties cannot be reduced to those of smaller parts. Although we can distinguish parts in any living system, the nature of the whole is always different from the mere sum of its parts.

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Systems thinking was raised to a new level during the past twenty years with the development of a new science of complexity, including a whole new mathematical language and a new set of concepts to describe the complexity of living systems.

Examples of these systems abound in nature. Every organism—animal, plant, microorganism, or human being—is an integrated whole, a living system. Parts of organisms—e.g. leaves, or cells—are again living

systems. Throughout the living world, we find systems nesting within other systems. And living systems also include communities of organisms. These may be social systems — a family, a school, a village — or ecosystems.

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 principles of organization. This means that systems thinking can be applied to integrate academic disciplines and to discover similarities between phenomena at different levels of scale — the individual child, the classroom, the school, the district, and the surrounding human communities and ecosystems.

The principles of ecology are the principles of organization that are common to all these living systems. If you wish, they are the basic patterns of life. Indeed, in human communities, they could also be called the principles of community.

Now, of course, there are a lot of differences between ecosystems and human communities. There is no culture in ecosystems, no consciousness, no justice, no equity. So we can't learn anything about these human values from ecosystems. But what we can learn and must learn is how to live sustainably. Over more than three billion years of evolution, ecosystems have organized themselves so as to maximize sustainability. This wisdom of nature is the essence of ecoliteracy.

THE WEB OF LIFE

So, how do ecosystems organize themselves? Well, the first thing we recognize when we observe an ecosystem is that it is not just a collection of species but a community, which means that its members all depend on one another. They are all interconnected in a vast network of relationships, the web of life.

Understanding ecosystems, then, leads us to understanding relationships. This is a key aspect of the systemic understanding that is central to ecoliteracy. It implies a shift of focus from objects to relationships. A vibrant community is aware of the multiple relationships among its members. Nourishing the community means nourishing these relationships.

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Now, understanding relationships is not easy for us, because it is something that goes counter to the traditional scientific enterprise in Western culture. In science, so we have been taught, we measure and weigh things. But relationships cannot be measured and weighed; relationships need to be mapped. You can draw a map of relationships, interconnecting different elements or different members of a community. When you do that, you will discover certain configurations of relationships that appear again and again. This is what we call patterns. The study of relationships leads you to the study of patterns.

MATTER AND FORM

And here we discover a tension that has been characteristic in science and philosophy throughout the ages. It is a tension between two approaches to the understanding of nature, the study of matter and the study of form. 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; to measuring and quantifying. The study of form asks, “What is the pattern?” And that leads to the notions of order, organization, relationships. Instead of quantity, it 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. In many traditional cultures, in the East and in the West, the study of patterns and relationships has been favored. In Western science, by contrast the study of matter — of quantities and constituents — has dominated. But in recent decades the rise of systems thinking has brought the study of form — of patterns and relationships — to the fore again. The main emphasis of chaos and complexity theory is on patterns. The strange attractors of chaos theory, the fractals of fractal geometry — all these are visual patterns. The whole new mathematics of complexity is essentially a mathematics of patterns.

ART AND EDUCATION

As I said before, when you study a pattern, you need to map a set of relationships, whereas the study of matter is the study of quantities that can be measured. Understanding patterns requires visualizing and mapping. This is the reason why, every time the study of pattern was in the forefront, artists contributed significantly to the advancement of science. In European history, the two most famous examples are Leonardo da Vinci, whose whole scientific life was a study of pattern, and the German poet Goethe in the eighteenth century, who made significant contributions to biology through his study of pattern.

The study of pattern, then, is central to ecology. For educators, this recognition should be important also because it opens the door for integrating the arts into the school curriculum. There is hardly anything more effective than the arts — whether it's the visual arts, music, or the performing arts — for developing and refining the child's natural ability to recognize and express patterns. Thus, the arts can be a powerful tool for teaching systems thinking, in addition to enhancing the emotional dimension that is increasingly being recognized as an essential component of the learning process.

THE PRINCIPLES OF ECOLOGY

When systems thinking is applied to the study of the multiple relationships that interlink the members of the Earth Household, a few basic principles can be recognized. They may be called principles of ecology, principles of sustainability, or of sustainable communities; or you might even call them the basic facts of life. We need a curriculum that teaches our children these fundamental facts of life —

- that an ecosystem generates no waste, one species' waste being another species' food;
- that matter cycles continually through the web of life;
- that the energy driving these ecological cycles flows from the sun;
- that diversity assures resilience;

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- that life, from its beginning more than three billion years ago, did not take over the planet by combat but by cooperation, partnership, and networking.

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PROJECT-BASED LEARNING

Because of its intellectual grounding in systems thinking, ecoliteracy offers a powerful framework for the systemic approach to school reform that is now widely discussed among educators. Systemic school reform is based on, essentially, two insights: a new understanding of the process of learning and a new understanding of 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. The new understanding recognizes the active construction of knowledge, in which all new information is related to past experience in a constant search for patterns and meaning; the importance of experiential learning; of diverse learning styles involving multiple intelligences; and of the emotional and social context in which learning takes place.

The new understanding of the learning process suggests corresponding instructional strategies. In particular, it suggests designing integrated curriculums, emphasizing contextual knowledge, in which the various subject areas are perceived as resources in service of a central focus. Project-based learning is the ideal way to achieve such an integration. As you know, project-based learning consists in facilitating learning experiences that engage students in complex, real-world projects through which they develop and apply skills and knowledge.

THE SCHOOL GARDEN

At the Center for Ecoliteracy, we recommend growing a school garden and using it as a resource for cooking school meals as the ideal project for experiencing systems thinking and the principles of ecology in action, and for integrating the 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 school.

In the garden, we learn about food cycles and we integrate the natural food cycles into our cycles of planting, 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.

A SENSE OF PLACE

Through gardening, we also become aware how we ourselves are part of the web of life; and thus, over time, the experience of ecology in nature gives 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. “Places,” writes David Orr, “are laboratories of diversity and complexity, mixing social functions and natural processes... The study of place enables us to widen our focus to examine the interrelationships between disciplines and to lengthen our perception of time.”

GROWTH AND DEVELOPMENT

In the garden, we observe and experience the life cycle of an organism — the cycle of birth, growth, maturation, decline, death, and new growth of the next generation. In the garden, we experience growth and development on a daily basis. We can follow the development of a plant from the seed to the first shoot, the growth of the stem and leaves, the buds, the flowers, and the fruits. And when we look into a fruit, we find that at its very core are the new seeds; and so the life cycle begins again.

The understanding of growth and development, of course, is essential not only for gardening but also for education. While the children learn that their work in the school garden changes with the development and maturing of the plants, the teachers’ methods of instruction and the entire discourse in the classroom changes with the development and maturing of the students.

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Since the pioneering work of Jean Piaget in the 1920s and 30s, 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 — 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 one of the best ways for children to become ecologically literate and thus able to contribute to building a sustainable future.

SHARED LEADERSHIP

It is obvious that integrating the curriculum through gardening, or any other ecologically oriented project, is possible only if the school becomes a true learning community. The conceptual relationships among the various disciplines can be made explicit only if there are corresponding human relationships among the teachers and administrators.

In such a learning community, teachers, students, administrators, and parents are all interlinked in a network of relationships, working together to facilitate learning. The teaching does not flow from the top down, but there is a cyclical exchange of information. The focus is on learning and everyone in the system is both a teacher and a learner. Feedback loops are intrinsic to the learning process, and feedback becomes the key purpose of assessment. Systems thinking is crucial to understand the functioning of learning communities. Indeed, as I have mentioned, the principles of ecology can also be interpreted as principles of community.

Finally, the systemic understanding of learning, instruction, curriculum design, and assessment can only be implemented with a corresponding practice of leadership. This new kind of leadership is inspired by the understanding of a very important property of living systems, which has been identified and explored only recently. Every living system occasionally encounters points of instability, at which some of its structures break down and new structures emerge. The spontaneous emergence of order — of new structures and new forms of behavior — is one of the hallmarks of

life. In other words, creativity — the generation of forms that are constantly new — is a key property of all living systems.

Leadership, therefore, consists to a large extent in continually facilitating the emergence of new structures and incorporating the best of them into the organization's design. This type of "systemic" leadership is not limited to a single individual but can be shared, and responsibility then becomes a capacity of the whole.

COMPONENTS OF ECOLITERACY

Well, these are, very briefly, the main components of ecoliteracy. I have tried to show you how systems thinking forms the intellectual core of this framework; a core that allows us to integrate the various components. Let me summarize these components:

1. understanding the principles of ecology, experiencing them in nature (e.g. in a school garden), and thereby acquiring a sense of place;
2. incorporating the insights from the new understanding of learning, which emphasizes the child's search for patterns and meaning;
3. implementing the principles of ecology to nurture the learning community, facilitating emergence, and sharing leadership;
4. integrating the curriculum through project-based learning with special focus on school gardens.

You can see from this summary that ecoliteracy is much more than environmental education, which is one of the four components. You can also see that project-based learning is an essential and integral part of ecoliteracy.

As our century comes to a close and we go toward the beginning of a new millennium, the survival of humanity will depend on our ability to understand the principles of ecology and live accordingly. This is an enterprise that transcends all our differences of race, culture, or class. The Earth is our common home, and creating a sustainable world for our children and for future generations is our common task.

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