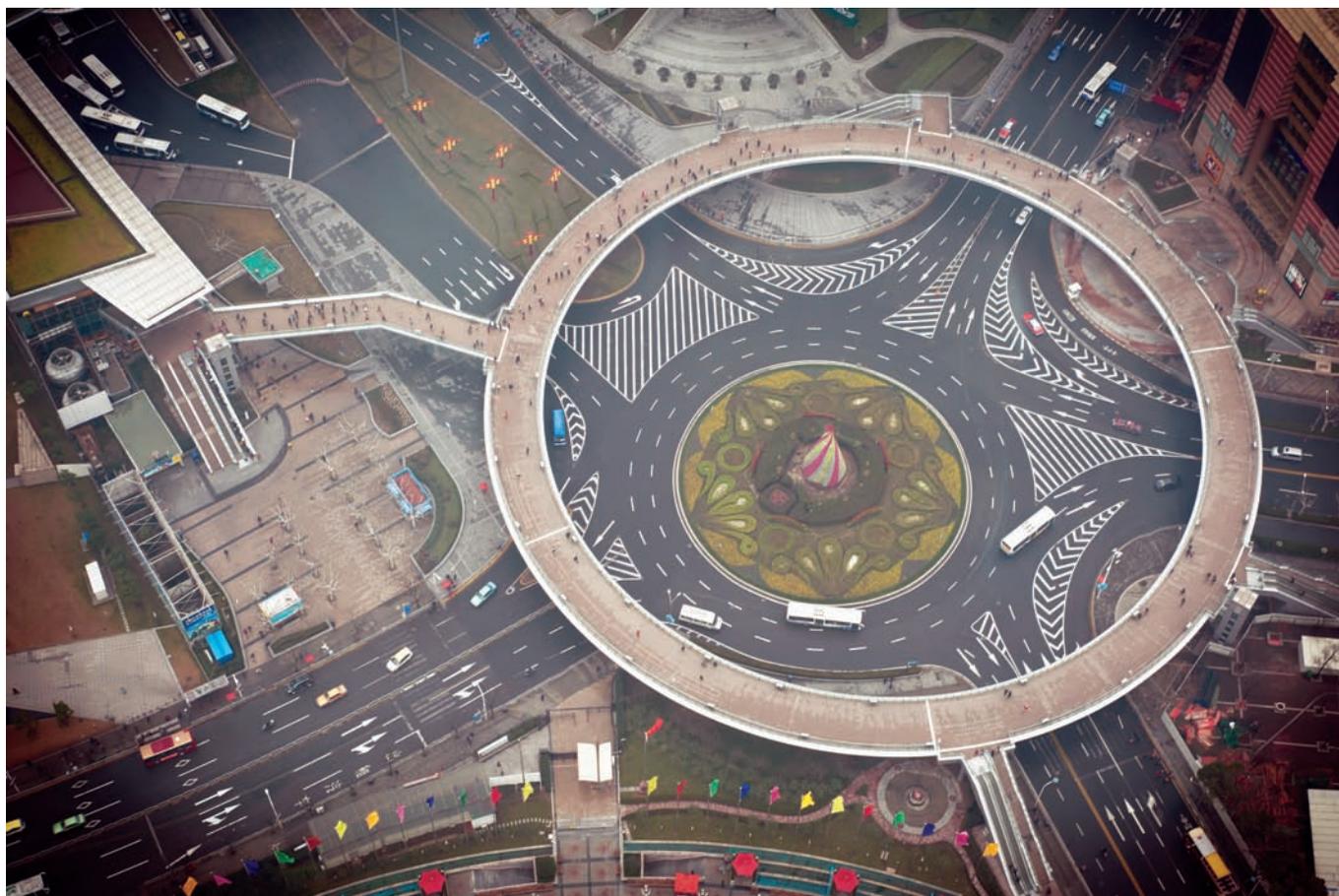

Feature

Learning to Connect the Dots: Developing Children's Systems Literacy

by **Linda Booth Sweeney**



Tauno Tõhk

A brief interaction between the author and her four-year-old son at a traffic rotary illuminates the awareness young children have, often overlooked, of systems and connectedness.

In Brief

How can adults nurture children's capacity to "connect the dots" through everyday conversations and activities? How can educators build an environment that leads children to see the patterns that make a difference? In this article, educator and writer Linda Booth Sweeney points out that thinking about systems means paying attention to the interrelationships, patterns, and dynamics that surround us—and that children are naturally attuned to this. In cultivating systems literacy, you build upon this natural understanding to help promote this integrated way of thinking for the children in your life.

The road construction project around the local rotary had been going on for over a year. As a result, the whole town was cranky. One afternoon, my son and I drove the rotary just before 5:00 p.m., along with throngs of irritable commuters, anxious to get home. Tempers were short and the sound of car horns pierced the air. Pointing to the tangle of traffic in front of us, my then four year-old asked: “Mommy, what happens when everyone says me first!?”

I was used to his asking questions. Typically, Jack asked about categories (“Animals aren’t people, are they?”), or how things work (“Why do bees kiss the flowers?”) or facts (“How hot is the center of the earth?”). This question was different; this one had to do with causes and consequences. I considered talking to him about the cost of maximizing individual gain, but held back and asked instead, “What do you think would happen if everyone said me first!?”

He pressed his nose against the window, paused, and said, “Well, there might be a lot of accidents. Or maybe even a huge crash!”

“Can you think of other times when everyone says me first?” I was thinking about overfishing, gas guzzlers, and our overcrowded community pool.

Jack responded, “You know how you said it’s not good to let the water run when we brush our teeth, ‘cause if everyone did that the reservoir would go down?” Well, it’s kind of like that.”

At the age of four, he was aware enough of the general notion of systems—two or more parts that interact to form a whole—to make a complex observation: the rotary and the reservoir were common resources. Like water, air, and playgrounds, these are resources that many people use, and for which no individual is solely responsible. Moreover, in asking the question, “What happens when everyone says me first!?” he recognized the impact of individual decisions on the larger whole. Without knowing it, he stepped right into the middle of the greatest

dilemma in commons-related issues: each individual action is defensible on its own, but they can combine to have a devastating impact on the larger whole.

Many children intuitively grasp the nature of systems, as Jack did. They can see, for instance, how a common but limited resource, such as water, air, land, highways, fisheries, energy, or minerals becomes overloaded or over-used, and how everyone experiences diminishing benefits. However, these children don’t always have many opportunities to develop those insights into a systems awareness that will serve them all their lives. Parents, educators, and other adults can help them learn to “connect the dots”: to see beyond the surface, to recognize interconnections and

Key Concepts

- Children possess an innate understanding of complex systems.
- This understanding is crucial to solving the interlinked social, environmental, and economic problems of today's world.
- Education for children of all ages can and should be designed to nurture this systems-based intuition.

dynamics among people, places, events and nature, and to begin thinking about how to use those interconnections to improve their world.

Where do our children learn to think this way? How do you nurture a child’s natural intelligence about systems and help him or her to become systems literate? How can you confirm for your children what they already know: that their world is interconnected and dynamic, a tightly woven web of related, interacting elements and processes, and as such, is indeed meaningful? How can this insight become an underlying learning aesthetic with which they can build their lives?

Why Systems Literacy Matters

Children today are growing up in a world in which oil spills, global warming, economic breakdowns, food insecurity, institutional malfeasance, biodiversity loss, and escalating conflict are commonly at the top of the news. For children to make sense of these trends, they must become aware of the causes and consequences in a slew of interconnected systems, including families, local economies, the environment, and more. Ideally, we want our children to take what Edith Cobb, author of *The Ecology of Imagination in Childhood*, calls “a reticulate approach”¹ (resembling a net or network) to knowledge and sense-making.

To be literate means to have a well-educated understanding of a particular subject, like a foreign language or mathematics. In many fields, the knowledge must be both comprehensive and abundant enough that you are capable of putting it to use. Systems literacy represents that level of knowledge about complex interrelationships. It combines *conceptual knowledge* (knowledge of system principles and behaviors) and *reasoning skills* (for example, the ability to see situations in wider contexts, see multiple levels of perspective within a system, trace complex interrelationships, look for endogenous or “within system” influences, have awareness of changing behavior over time, and recognize recurring patterns that exist within a wide variety of systems).

When people aren’t literate about systems, too many human activities are like those cars jammed into the roundabout: unaware of the pattern that connects them and, thus, prone to exploitive and destructive results. Systems literacy is a prerequisite for realizing the kinds of aspirations that people increasingly have in an interconnected world, but that seems impossible to achieve from a fragmented point of view. As the poet, novelist, and essayist Wendell Berry

puts it, “We seem to have been living for a long time on the assumption that we can safely deal with parts, leaving the whole to take care of itself. But now the news from everywhere is that we have to begin gathering up the scattered pieces, figuring out where they belong, and putting them back together. For the parts can be reconciled to one another only within the pattern of the whole thing to which they belong.”²

When children learn about systems and become more explicitly systems literate, their worldview shifts. In *The Power to Transform*, Stephanie Pace Marshall explains that the value of nurturing systems literacy comes from “the power of an alternative worldview.” She continues, “When we perceive and experience wholeness, we are transformed. We no longer see nature, people, events, problems, or ourselves as separate and unconnected.”³

One natural consequence is greater compassion for others. This is a part of peoples’ makeup that can get suppressed by the prevailing culture in many places, but that can be uncovered and drawn out by experience and learning. When children look for the connection between themselves and other people, places, events, and species, they no longer feel like outsiders looking in at others’ worlds. They are now insiders, experiencing the connection to “other” as the farmer is connected to the soil and the salmon is connected to the river.

Another consequence is that children start to see themselves as part of, rather than outside of, nature. Imagine that a 12-year-old, living in a suburban village, is presented with two pictures of a lawn. The first is filled with wildflowers and looks somewhat messy and random. The second is lush, green, neat, orderly, well-groomed, and obviously well-fertilized. Which is more beautiful? The second image, of course, represents the way that a beautiful

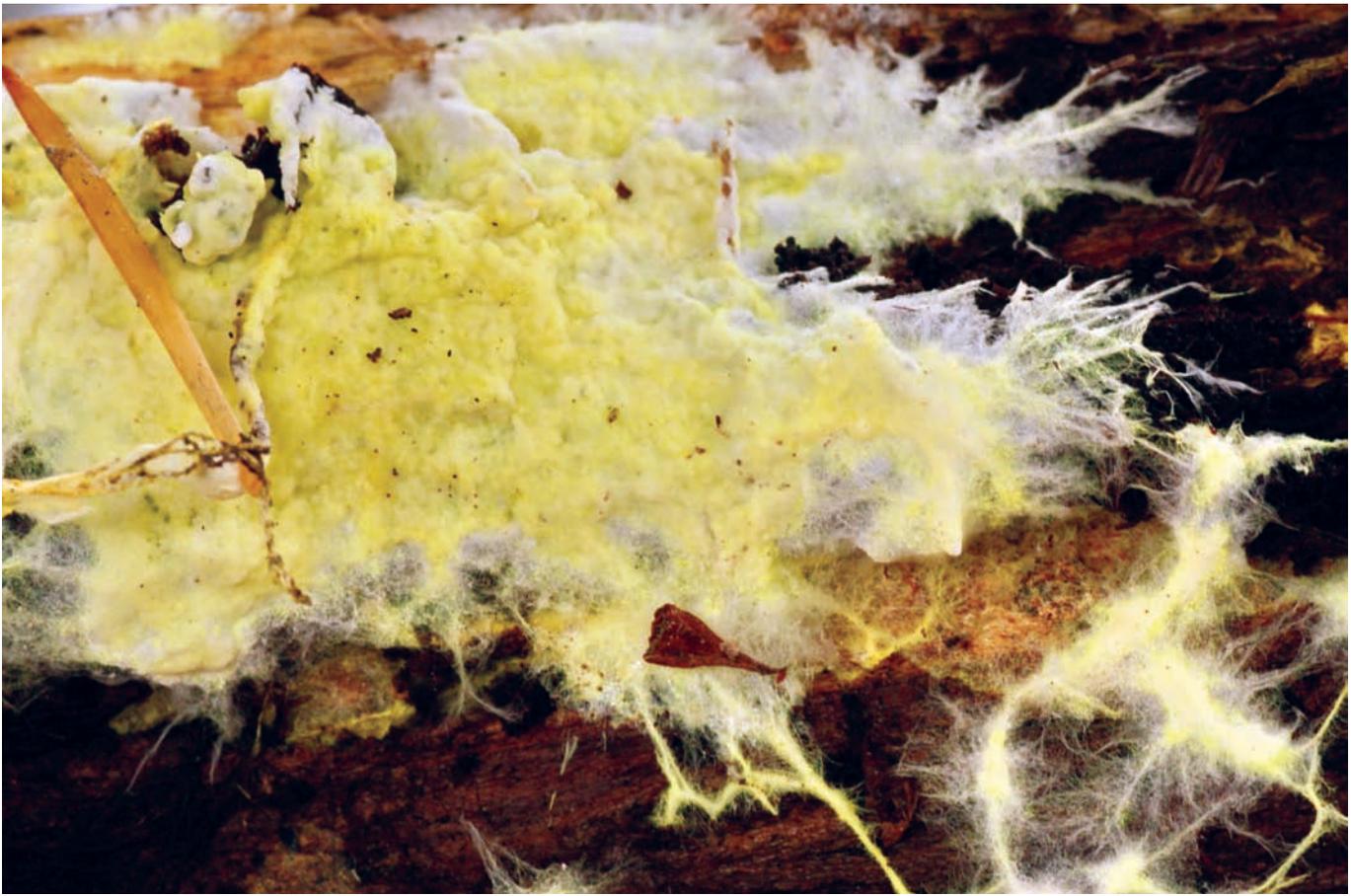


Jessica Lucia

Systems literacy can fortify the connection between children and the natural world as it helps them understand the complex balance on which a healthy ecosystem depends, argues the author.

lawn is conventionally expected to look in many communities, and many 12-year-olds would pick it, but a systems-literate student might well prefer the disorderly lawn. He or she would know that that the lawn *worked* with the landscape’s natural processes, encouraging a diverse group of plants and animals to grow, maintaining its own ecological balance, and adding little or no waste to the ecosystems around it. On the other hand, the orderly, straight, groomed lawn could only survive by contradicting natural processes. It would require ongoing management and its continued success would lead to a variety of unintended negative consequences: greenhouse gas emissions from the lawn mower, use of fossil fuels to make chemical fertilizers and treatments, the death of beneficial insects from pesticides, the added economic costs of lawn supplies and maintenance, the stress it puts on the family’s budget, the removal of some plants while allowing others to overrun the ecosystem (potentially causing the need for more pesticides), and the run-off of chemicals into local water sources with unknown effects.

As they grow up and learn about the economy, climate, education, energy, poverty, waste, disease, war, peace, demographics, and sustainability, children who are systems literate will tend to look at all these issues as interrelated. From the systems perspective, nothing stands alone: my climate is your climate, your infectious disease is my infectious disease, your food shortage is my food shortage. Systems literacy makes people less likely to blame a single cause for challenges and problems. Instead, it becomes a habit to look for recurring patterns that exist among a wide variety of systems, to seek out indicators of interrelated causes (knowing that very complex causes can leave deceptively simple tracks), and to anticipate how the functioning of a living system will change if a part or a process is changed. Systems thinkers recognize that big actions can have small consequences—and vice versa. They seek diversity, knowing that living systems depend on the variety, complexity, and abundance of species to be healthy and resilient. They look for closed loops of production and



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Systems thinking requires understanding change over time, noting the connection between overlapping cycles, as when a fungus, like this one, spreads across a downed and decaying log.

consumption, where waste from one source can be “food” for another. They question the assumption that bigger is always better.

Paying attention to living systems also raises awareness of the Earth’s (or biosphere’s) pace of change, often in stark contrast to the hurried, mechanistic pace of the technosphere. Systems literacy makes it easier to see the commons: the shared gifts of nature such as water, air, land, fish, and also the shared efforts of our communities, upon which we depend, and for which we are all responsible.

Learning about systems, and about living systems in particular, can help children come to a deeper, more compassionate, more accurate, and more sustainable sensibility about what is beautiful, what is peaceful, and what is essential.

Changing the Learning Aesthetic

When we ask students to move beyond simple, linear explanations of causes, we are asking them to be literate about systems. Yet most adults in the U.S., including most industry and government leaders, were not explicitly taught skills related to seeing systems of multiple causes, effects, and unintended impacts. Rather, people were taught that the best way to understand a subject was to analyze it or break it up into parts. Research in dynamic decision making shows that when adults are faced with dynamically complex systems—containing multiple feedback processes, time delays, nonlinearities, and accumulations—performance is biased and suboptimal.⁴

Herein lies an intriguing opportunity. When it comes to developing greater literacy about systems, most adults are learning along with their children. Rather than an obstacle to children’s learning, this could be a major asset. For most students, co-learning (with parents, teachers, or peers) offers a chance to take an active role and develop higher-order skills such as critical and divergent thinking, analysis, synthesis, and problem solving.

Most classroom structures today do not encourage system literacy. While the world is becoming increasingly more complex, educators can find themselves continuing to fragment knowledge and real world problems through compartmentalized curricula; science is taught in one class, math in another, English in another.

Courses in natural science focus on the material world, while courses in the social sciences focus on the social world, and neither class acknowledges the intensive, ongoing ways in which these two worlds influence each other. When we talk to children about issues, such as climate change, terrorism, and water use, we can raise their awareness of the material and social worlds, bringing together insights from history, biology, and literature, as well as the daily newspaper. Most importantly, we can come to richer understandings by tapping into the experience and insight that children already have. Conversations with Fritjof Capra helped me clarify this division between the natural and social sciences. According to Capra, “this division will no longer be possible, because the key challenge of this new century—for social scientists, natural scientists, and everyone else—will be to build ecologically sustainable communities, designed in such a way that their technologies and social institutions—their material and social structures—do not interfere with nature’s inherent ability to sustain life.”⁵

Everyday Ways to Foster Systems Literacy

Some experts in the field have argued that, because systems operate in non-linear ways that can be difficult to assimilate, systems thinking requires access to advanced training in complex systems theory, system dynamics, and agent-based modeling. Certainly, these fields of study can help people move beyond natural, intuitive understanding of systems to more expert levels of systems literacy. At the same time, there is a growing body of research (including my own research with 10- and 11-year-olds) that shows that many students intuitively “think about systems,” both natural and social, without any formal training and long before they’re ready for graduate school. Children as

young as four and five show a capacity for understanding systems behaviors, which suggests that systems thinking may be part of a child’s innate intelligence that is “corrected” by adults who have been taught to compartmentalize phenomena.⁶

R.W. Kates and C. Katz studied three-to-five year olds and their understanding of the hydrologic water cycle. These researchers found that “some sense of cycles” (e.g., the domestic water cycle and the cloud-rain cycle) existed among the four-year-old children, while the five-year-old group described “a more complex and extensive hydrology.”⁷

Without knowing it, he stepped right into the middle of the greatest dilemma in commons-related issues: each individual action is defensible on its own, but they can combine to have a devastating impact on the larger whole.

Piaget, who was familiar with Austrian-born biologist Ludwig von Bertalanffy’s notion of “open systems,” recognized this natural systems intelligence when he observed: “There is in the child...a spontaneous belief that everything is connected with everything else and that everything can be explained by everything else.”⁸

We see this natural intelligence in young people who partake in role-playing games such as *Dungeons and Dragons* and computer games like *Zoo Tycoon* and *SimCity*. In the thick of this “play,” children track numerous interdependencies, manage large amounts of data, and anticipate unintended consequences. In play, they flex their systems thinking muscles.

Opportunities for nurturing systems literacy in children are all around us, from the classroom and the playground to the car, the library, the dinner table, a school garden,

the bath, and the grocery store. With a thoughtful guide, the great outdoors offers a fertile classroom for understanding the interrelationships and dynamics of species. Time in nature is not just healthy (as Richard Louv, author of *The Nature Principle: Human Restoration and the End of Nature-Deficit Disorder*, reminds us), it is also important if we are to learn to live sustainably with our natural environment. Buckminster Fuller, the American engineer, systems theorist, author, designer, and creator of the geodesic dome, also pointed to the concept of nature-as-teacher: “I am confident that humanity’s survival

depends on our willingness to comprehend feelingly the way nature works.”⁹ Why not encourage the seven-year-old child, enthralled with the life cycle of a butterfly, to explore other “life cycles?” Or wonder, with the 10-year-old fishing enthusiast, how a worm in the garden may be useful for his next fishing trip, but also useful as a soil tiller and a potential food source for a hungry robin. In these ways, we can give children direct experiences with unadulterated nature so that they, as Masanobu Fukuoka, farmer, and author of *The One-Straw Revolution* urges, “... can instinctively understand what needs to be done and what must not be done—to work in harmony with (nature’s) processes.”¹⁰

Here are some other examples of conversations and activities that can help young people become more systems literate:

Help children to connect the dots.

Set an example: talk about relationships, not just things. Instead of simply saying, “That’s a brown chicken,” point out that the chicken lays eggs and eats the insects in the farmer’s garden. Recognize and encourage the child’s natural tendency to see a network of possible causes and consequences. Ask the child to draw the connections he or she sees among cars, air, plants, and people.

Simple cause-and-effect diagrams can help to reveal the patterns underlying sticky problems. For instance, think of an ongoing household battle. Perhaps your son hates to clean his room and you really don’t like to ask

nature, they are goal-seeking, working to bring things to a desired state and keep them there.

Once you see this pattern, you can look for ways to break it. One strategy is to revisit and reset the goal. Perhaps your standards as a parent are too high—you’re looking for the pristine child’s bedroom that one might see in *House and Garden*—while your child’s are too low. Can you develop a “maintenance” goal that both parent and child agree upon? Since that may not be enough to overcome this ingrained systemic structure, can you also add in a link to the system, such as planned clean-up time twice a week, to achieve the maintenance goal?

returning on a regular basis to see how it changes. Examples might include a tree with leaves that turn color, a pond whose water level rises or falls, or a place with a barometer and thermometer. Encourage them to leave a small notebook near their sit spot so they can keep track of the changes they observe over time.¹¹

Look for the patterns that repeat.

When a child observes drivers’ behavior at the traffic rotary being similar to people letting the water run when they brush their teeth, or that the growing conflict between two kids at school is similar to the escalating conflict between two nations, compare those patterns. Give your own nicknames to the patterns you see. For instance, you might call that escalating conflict “snowballing,” and then when a fight between siblings begins to escalate at home, you can ask, “Are you snowballing now yourselves?”

Many Dr. Seuss books, like *The Lorax*, *The Sneetches*, and *The Butter Battle Book*, have great examples of balancing and reinforcing feedback.¹²

From the systems perspective, nothing stands alone: my climate is your climate, your infectious disease is my infectious disease, your food shortage is my food shortage.

him to clean his room. Throughout the week, you remind him about the chore. Your son resists. By the end of the week, your frustration is boiling over. Finally, you threaten a week of no TV and your son relents. When he shows his clean room, you are happy. But the next day, with the pressure off, he slowly reverts to his old habits. Mid-way through the week, you feel your frustration build again, this time with more pressure.

One way out of this dilemma is for you and your son or daughter to sit down together, and each draw simple diagrams showing the situation as you see it.

By connecting the dots, both sides can see that you’re caught in a closed causal loop. It is a balancing feedback process, a set of interactions that return a system—like your body, an ecosystem, market systems—back to a state of equilibrium. By their very

Talk about change over time.

Trace and anticipate changes over days, months, and years. For example, a child may notice the slow decay of a fallen tree in a park or in the back yard. Or you may point out less obvious changes, such as the changes in a pasture when chickens are allowed to roam free.

You can work with your child to draw simple line graphs to track behavior over weeks or months—anything from the levels of happiness at school to the money in your savings account to the number of beavers in the pond. Once you have a graph and you can see some behavior rising, falling, or oscillating, ask: what set of interrelationships might be causing this pattern?

For a personal demonstration of change over time, encourage children to find a “sit spot” where they can focus on some outdoor phenomenon,

Change perspective.

When there’s a case of bullying at school, try to talk about the perspectives of the aggressor, the target, the teachers, and the bystanders. Create a role play so the students can act out the situation or problem from different perspectives. What new ideas or insights come from changing some of the situational factors—such as how close they stand to each other when they tell the story?

Anticipate unintended consequences.

Take a rubber band and stretch it, saying, “Let’s have some fun and see how far we can stretch how we look at time.” Unstretched, the rubber band may represent a day; stretched, it may represent five years into the past and five years into the future. By doing this, we are asking the young person to

adopt what sociologist Elise Boulding called, “the extended present,”¹³ a view of time that extends the present to five, 50, or 200 years ahead and behind. For example, disposable diapers take between 100 and 500 years to decompose. Talk about the fact that no one knows exactly how long it takes, because no one has lived long enough to see it happen. The extended sense of the present is particularly appropriate for living systems, because many living systems, both natural and social, don’t generate a full cycle of behavior over short time intervals. You won’t understand the seasonal cycle of your garden, for instance, if you observe it for only a day or two.

Think like a bathtub.

Make it a game to look for things that build up or accumulate. A bathtub for instance, accumulates water. System dynamicists call these accumulations stocks. Trees, fish, people, goods, good will, money, the national debt—these are all stocks. The rate at which the stock changes is its *flow*. Challenge children to think in terms of stocks and flows. For instance, you can ask: If the water is draining out of the bathtub twice as fast as it is flowing in, what happens to the level of the water in the tub? (The answer: The level goes down!) What if the amount of CO₂ emissions flowing into the atmosphere is flowing in at twice the rate that it is being drained out (through, for example, carbon sinks)? What happens to the amount of CO₂ in the atmosphere? (The answer: the amount increases, which is actually what is happening today.)

Stocks and flows play a key role in generating some of the most perplexing dynamics we encounter. Studies of the pesticide DDT, for example, have shown that while DDT evaporates from the surface of plants and buildings over six months, it remains in the tissue of fish for up to 50 years. The amount of DDT in fish tissue is a stock with very slow outflow. We need to



Howard County Library System

To make sense of today’s world—one fraught with, global warming, economic breakdowns, food insecurity, institutional malfeasance, and escalating conflict—children must be taught to connect the dots between cause and consequence within interconnected systems.

understand these accumulations to understand the source of many of the major challenges we face today—economic, social, and environmental.

When we look at stocks and flows we understand, for instance, that a deficit (the rate at which a country borrows money) is a flow and the national debt is a stock. We understand, as well, that taking the national deficit down to zero doesn’t necessarily mean that we will get rid of the debt. We also understand that carbon dioxide stocks in our atmosphere will continue to increase if the rate at which carbon dioxide flows into the atmosphere is greater than the rate at which it drains out—an important insight in the application of carbon emissions reduction.

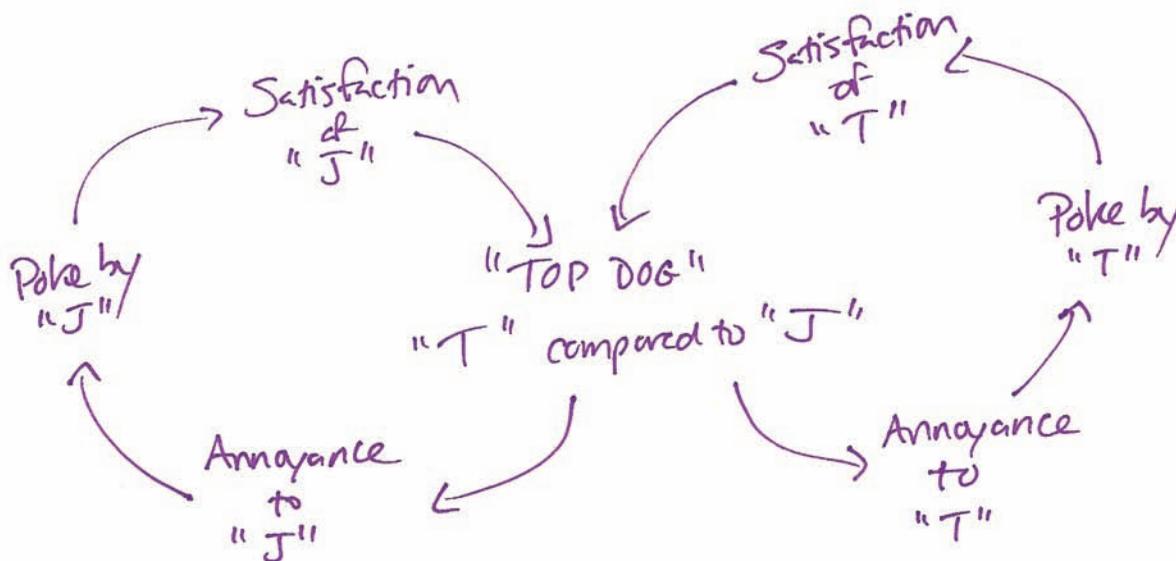
From Awareness to Action

With the help of adults, children’s intelligence about systems can be developed further, into models of better problem definition, problem solving, and design. This enables them to analyze and act in informed ways; aware of recurring patterns, they

will be less likely to react viscerally and ineffectively and more likely to understand the patterns of behavior. They can use this understanding to correct their own actions, anticipate unintended consequences, and help others operate more effectively.

When children are systems literate, they help their parents learn, as well. For example, they can talk about and make visible “commons dilemmas”—those conflicts that arise around shared resources for which everyone is mutually responsible.

My four-year old at the rotary is now a strapping 13 year-old. Not long ago, he ended up in a not-so-playful snowball fight with his brother. I took each one aside to find out what was going on. They both told a similar story: A cutting comment from one led the other to comment back, which led the first boy to poke, the second boy to squash, and then prompted both to an out-and-out battle. This was an example of the common pattern called escalation. Feeling at my wit’s end, I quickly sat them down and sketched a diagram that looked like this:



Linda Booth Sweeney

After her two sons fell into argument, the author presented them with this diagram to help illustrate how positive feedback, in their case, could lead to endless escalation.

“Look,” Jack said, “it’s a figure eight lying on its side. That’s infinity. This thing could go on forever.”

“And just keep getting worse,” his brother groaned.

As we talked about it, we realized together that the growing conflict was driven by each one trying to “out-cool” or “top-dog” the other. The more “cool” behavior one kid put on, the more the other wanted to squash it. Suddenly, they saw themselves as part of the “system,” rather than separate from it. They “got” that blaming each other wasn’t going to solve the problem. When they could see how their actions were actually fueling the actions of the other, with the help of a simple picture, they then could talk about how they might break the cycle. When I asked what they could do differently, the answer came easily. The poker would lighten up on the poking, and the squasher wouldn’t squash so much.

The rotary, of course, has long since been fixed; traffic is back to normal. In our family, we try to do our part to solve the problem of the commons. Though I still rely on the car to drive to soccer practice, we walk to buy groceries and we

share eggs with neighbors from our own chickens. We try to talk in ways that make it easier to connect the dots in everyday situations. A common phrase in our house these days—*what if everyone did that?*—is our way of attempting to magnify the consequences of our individual actions so that we can imagine the broader impact.

Everyone is born with a natural intelligence about living systems. With just a little effort, you can encourage that natural intelligence in young people and remind them that their world is interconnected and dynamic, a tightly woven web of nature, people, issues, and events, and as such, it is both purposeful and meaningful. **S**

Author’s Note: To learn more about fostering systems literacy in a variety of settings, see: Tina Grotzer’s *Learning Causality in a Complex World: Understandings of Consequence* (Lanham, MD: R&L Education, 2012); Daniel Goleman, Lisa Bennett, & Zenobia Barlow’s *Ecoliterate: How Educators Are Cultivating Emotional, Social, and Ecological Intelligence* (San Francisco: Jossey-Bass, 2012); and Draper Kauffman’s classic text, *Systems 1: An Introduction to Systems Thinking* (Waltham, MA: Pegasus Communications, 1980).

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