3. Context and Engagement

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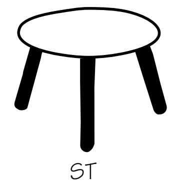

In 1988, the first systems thinking classes were started at Orange Grove Middle School in Tucson, Arizona, instigated by Frank Draper, a science teacher, and encouraged by Mary Scheetz, then Orange Grove's principal. When my wife, Diane, and I first visited Frank's eighth grade science class in 1991, it was hard not to notice that something was different. First, Frank was nowhere to be seen. In fact, there was no teacher in the room. A couple of students had some questions about their library research, and Frank had gone to the library with them (back in the pre-Internet walk-to-the library days). But, to our amazement, the classroom had not descended into chaos. Instead, the thirty or so students were glued to their new Macintosh computers, two to a machine, deeply engrossed in their conversations with one another.

We learned that Frank and his colleague Mark Swanson had built their semester science curriculum around a real project: the design of a new state park to be developed north of Tucson. After studying the sorts of conflicts that inevitably arise in park and wilderness area management, they were working with a STELLA-based simulation model that showed the impacts of different decisions. They had an overall budget and a prescribed mission based on environmental quality, economics, and recreation and education targets they had set out for the park. At the time, the students were working on designing the park's trail system. Once they laid out a proposed trail, the simulation model calculated the environmental and economic consequences, prompting energetic debates over tradeoffs among different options.

We had only been standing in the back of the room for a few minutes when a couple of young boys came over and grabbed us. "We need your opinion," Joe said. "Billy and I have different trails. He thinks his is great because it makes a lot of money (routing hikers past the best views), but it also does a lot of environmental damage. Mine does less environmental damage, but he thinks it's too close to the Indian burial grounds and will stir up protests."

We listened for a while as the two boys explained their different trails and showed us some of the simulated consequences. There were no black and white answers, and it was clear that they understood this. This was about design and making choices. The bell rang, signaling the end of the period, and they said goodbye, agreeing as they left to come back after school to see if they could agree on a proposal to share with the rest of the

This essay was adapted from part of "Education for an Interdependent World" in Joy Richmond, Lees Stuntz, Kathy Richmond, and Joanne Egner (editors), *Tracing Connections: Voices of Systems Thinkers*, (iSee Systems and Creative Learning Exchange, 2010). *Tracing Connections* was a commemorative volume in honor of Barry Richmond, a pioneer in systems thinking, managing director and founder of High Performance Systems, and designer/developer of the STELLA modeling software, who passed away suddenly in 2002.

class at the end of the week. (The students' proposals and analyses were presented to the actual park planning commission at the end of the term.)

The students also learned a variety of conceptual tools for mapping systems and for expressing and communicating with others about their understanding of the interdependence in developing a park plan. Today, tools like behavior-over-time graphs, connection circles, causal loop diagrams, stock-and-flow mapping, and system archetypes are introduced in this school system as early as kindergarten. These young children are invited to look at daily experiences like how trust builds or deteriorates in a friendship, or what happens during the process of breaking a bad habit. As students get older, they can naturally extend these tools to more complex subjects, and start to develop their own simulation models (see pages 148–150 and 275–292). This process develops not only deep content knowledge but thinking skills to see how common system dynamics can underlie very different situations.

"Our approach was to invite kids to consider a world view of complex interdependent systems. Instead of abstract learning, we use simulations to begin to confront and to penetrate this world of interdependence as it is embodied in particular real-life situations and how these systems relate to other systems," says Frank Draper.

ROOTS OF ENGAGEMENT

What was evident from the outset in the state park exercise at Orange Grove was the engagement of the students. What made them so involved?

First, the students were wrestling with real-world problems rather than artificial schoolroom exercises. They could identify not only with the challenges of developing a new state park but also with the benefits of designing the park well.

Second, the students were thinking for themselves. They knew there was no single right answer to the challenges they were facing. Ultimately, they had to understand more clearly what would happen if different decisions were made, and they had to frame the resulting trade-offs appropriately. No single formula was presented by the instructor to point to the right answer. Rather, the students had to sort out their own thinking about a real issue and explore different proposals, ultimately coming to their own conclusions.

Third, the teachers operated as mentors, not instructors. The teachers' role was not to give a prescribed method or guide the students to a predetermined right answer. Indeed, the teachers did not know the best outcome and were co-learners with the students. But the teachers' roles were no less crucial: they had to help the students make sense of the outcomes of different scenarios. Having been involved in building the computer simulation gave the teachers important knowledge for this task, but no simple answers. A complex dynamic simulation model will often respond to changes in ways that its developers do not anticipate, as different feedback interactions play out over time.

The entire process engaged both teachers and students in mutual learning around a complex domain. They had to recognize that they were working with a model and thus, by definition, their view was incomplete. One of the teachers' roles was to help the students describe the assumptions upon which the model was based and to invite the students to critique those assumptions and consider the implications of alternative assumptions, a critical aspect of scientific thinking.

For examples, see Diana Fisher's Math and Modelling Guides, page 291.

Fourth, working with partners drew the students into a joint inquiry. This not only enabled them to get to know one another but forced them to continually confront alternative views and assumptions. This drew students into a natural process of seeing how each reasoned, employing past experiences and assumptions to draw conclusions that guided actions. Appreciating this in the other made them more open to testing their own reasoning.

Of course, human beings follow such processes of inferential reasoning all the time, but it is often easier to see how this works in another person, since our own reasoning is often "transparent" or invisible to us. Educators understand the importance of reflection (i.e., learning how to examine our own assumptions and reasoning) in developing higher-order skills, but it remains an elusive educational goal, all but completely ignored by traditional schooling. Didactic instruction bypasses it entirely. Teachers' efforts to try to get students to reflect are easily undermined by teachers' authority and formal power, which intimidates students programmed to seek correct answers. As Scheetz said, reflection requires safety, which benefits from an environment of mutual inquiry. In this sense, students helping one another reflect is a powerful approach that goes well beyond teacher-centered strategies.

For example, consider the following (slightly stylized) interaction between Joe and Billy, working on their park trail system.

Billy: "Your trails are a bad idea because they are too close to the Indian burial grounds. You shouldn't do that."

Joe: "Who says? There are no rules that say we can't do that. They do a lot less environmental damage than yours."

Billy: "Yeah, mine are a problem. But which is worse?"

Joe: "I didn't really think about the burial grounds. Maybe there is a way to avoid the burial grounds and also do less environmental damage?"

Barry Richmond was an educator and lifelong student of systems thinking who designed and developed the modeling software STELLA. From his work with educators, Barry identified eight component skills of systems thinking skills. They were :

1. High-altitude thinking: to gain a view of the interdisciplinary big picture rather than the minutiae of any particular field of study

2. System-as-cause (endogenous) thinking: to distinguish the factors most relevant to an issue or behavior of interest and how they interact to generate observed behavior

3. Dynamic thinking: to visualize behavior patterns over time and see incidents as parts of patterns of behavior rather than isolated events

4. Operational thinking: to understand how the parts of a system interact to generate these patterns of behavior

5. Closed-loop thinking: to identify the web of interacting feedback loops (causal relationships) that link together all the interacting parts

6. Scientific thinking: to use mathematic models and simulation experiments as hypotheses, explaining the links between feedback and behavior

7. Empathic thinking: to inquire about working hypotheses and communicate

them effectively for individual and organizational learning

8. Generic thinking: to understand how certain feedback structures generate the same behavior in a variety of settings and contexts.

Also see Barry Richmond, "The Thinking in Systems Thinking: Eight Critical Skills," in *Tracing Connections: Voices of Systems Thinkers*, (iSee Systems and Creative Learning Exchange, 2010), page 3ff.

Billy: "Yeah, maybe, but I wonder how much less money we'll make; the park has to generate enough money to stay open. Let's try some other routes."

Today, many educators advocate for a "systems view" in education, but this simple interaction shows a critical but often missing element. The two boys are debating about the way specific features of a system interact over time in response to alternative actions—for example, how trail location affects the hiking patterns of visitors, the environmental effects, and park revenues. They step back to see how specific choices can have many different effects. They see different parts of the system interacting as a result of the choices they have made, and they adjust their choices accordingly. This is what the late pioneering educator Barry Richmond called "operational thinking." It was one of eight interdependent systems thinking skills that he saw as critically important. Other skills were also evident: The students were learning to see change—the consequences of how the park's trail system was laid out—as differing patterns of behavior over time, exhibiting dynamic thinking. And they learned how to formulate a hypothesis—what consequences they expected from different changes—and to test their expectations against a formal model of the system. They thus engaged in scientific thinking.

Operational thinking really comes alive when students can use interactive models to simulate and analyze the effects of different actions on overall system behavior. In concert with scientific thinking—where the model's assumptions are made explicit and challenged—even young learners can engage in sophisticated processes of building rigor and relevance.

The exchange also illustrates the dance of collaborative inquiry—thinking together about a complex matter. The boys are probing each other's ways of thinking through the design problem they face and making their own thinking more explicit in the process. In this way, collaboration and reflection become inseparable elements of mutual learning. They are helping one another; neither is right nor wrong; both are learning. Joe hadn't really thought about the Indian burial grounds as a constraint; this was outside the assumptions upon which he was operating. Likewise, Billy had not paid a lot of attention to the environmental damage of his trails because he was focused on maximizing hiker traffic and park revenues. Both conclude that there may be still better overall designs if they expand their assumption sets. In short, the boys are becoming more aware of their own taken-for-granted assumptions as they think through ideas together.

Of course, such interactions both build and depend upon mutual respect. It is easy to imagine two young boys simply arguing about who is right and never challenging their own reasoning. This is why educators like Scheetz understand that realizing the benefit of systems thinking tools is inseparable from deep and broad engagement of students, and that how, in turn, this depends on the overall school environment. As Scheetz says, "an environment where learning is likely to occur is one that is safe and secure and where taking risks is okay."

THE GLOBAL ACHIEVEMENT GAP

Why Even Our Best Schools Don't Teach the New Survival Skills Our Children Need—And What We Can Do About It, by Tony Wagner (Basic Books, 2008).

This book describes seven skills that people need to thrive in the world at large: critical thinking and problem solving, collaboration across networks and leading by influence, agility and adaptability, initiative and entrepreneurialism, effective oral and written communications, accessing and analyzing information, and curiosity and imagination. Wagner then describes how schools might evolve to foster these skills. Tracy Benson, praising this book, noted that many schools are using it as they develop curriculum and classroom approaches to prepare students for the twenty-first century. —Art Kleiner