NOTES AND INSIGHTS

Learner-directed systems education: a successful example

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System dynamics is a field built upon interactions. It only seems logical, then, that teachers, when attempting to bring alive the dynamic behavior of systems to their students, should use simulation models and interactive methods. We have been working this past year on developing interactive learning methods in our classrooms. This note is an attempt to show what a classroom can be once it has adopted an interactive approach to learning.

Before the advent of powerful personal computers (we have Macintosh SE computers with 20-megabyte hard drives) and STELLA and STELLAStack software, our students had a difficult time visualizing abstractions like dynamic systems. Today, as they build or manipulate computer models, they are also building mental models, mental constructs, and connections, and this is the ultimate goal of good teaching. For the first time they can see and think about real-life systems and manipulate them to see consequences in real time or compressed time. Students can formulate hypotheses about previously incomprehensible concepts and test the experimental model in a matter of minutes.

We are in the process of shifting our entire science curriculum in the Catalina Foothills School District to an interactive, systems-oriented delivery. We firmly believe all science content can be learned by students better through interactive methods than through traditional lecture/lab methods.

Our students, cooperatively learning in groups of two or three (not one), research and gather knowledge about natural systems. They then explore how these systems operate by selectively modifying components and seeing how they work in simulations of the real world. Following are five illustrations of interactive systems course-work using Macintosh computers, STELLA, and STELLAStack software that we have taught this past year.

Populations

Instead of reading or listening to a lecture about population dynamics, students, with teacher guidance, built a model of a human population. We had them build the models slowly, increasing the complexity and reality match of the models day by day. The students continually had chances to explain what they were building and seeing. By the fourth day we had the model shown in Figure 1.

Students then experimented with and discussed the implications of government policies that manipulate kids-per-couple, couples-percentage, and food-per-person. When tested a week later, with no further teaching on this subject, students were asked these questions: Why is it that just sending food to starving populations in Africa may make the problem worse in the long run? What can we do to help them work out a real solution?

The Macintosh SE computers used in our classrooms were donated by the Apple Classroom of Tomorrow Program of Apple Computer, Inc. STELLA and STELLAStack are trademarked products of High Performance Systems, Lyme, N. H.

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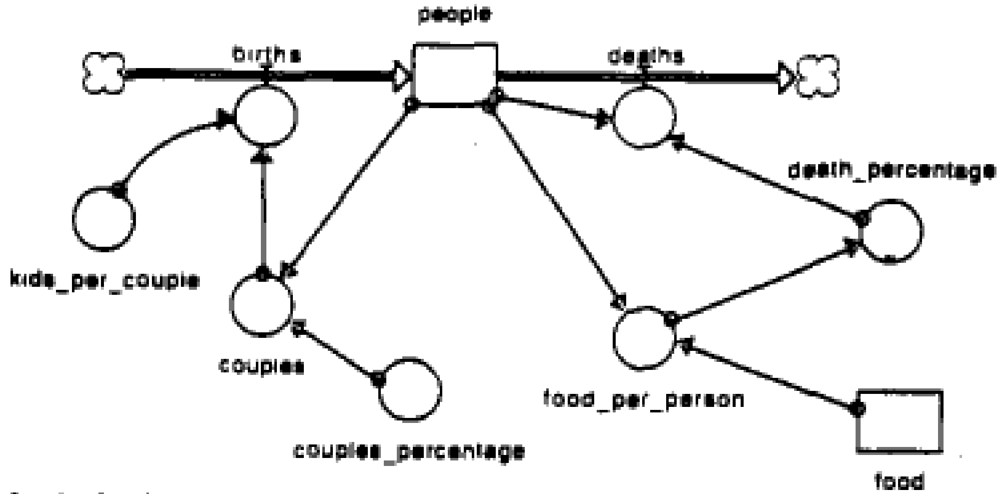

Fig. 1. Population model developed by students and teachers working together

food = food
INIT(food) = 200
people = people + dt * (births - deaths)
INIT(people) = 100
births = couples * kids_per_couple
couples = people * couples_percentage
couples_percentage = 0.4
deaths = people * death_percentage
food_per_person = food/people
kids_per_couple = 0.2
death_percentage = graph(food_per_person)
(0.0,0.500),(0.100,0.475),(0.200,0.430),(0.300,0.325),(0.400,0.258),(0.500,0.135),
(0.600,0.0575),(0.700,0.0100),(0.800,0.0),(0.900,0.0),(1.0,0.0)

We received several good answers, most of them talking about an increasing number of people surviving, which then makes the situation worse when the food runs out. One of the better answers said: "Sending food to Africa helps in the short term because the people have more food per person, which means more people are living, which raises the population. But if we stop giving aid, the food per person is even less than at the beginning. We can teach them how to grow more food and give them equipment." When you consider that this is from two l3-year-olds who had not looked at the population model for over a week, it is a pretty impressive answer. Granted they are not yet aware of the role of civil war and other political influences in the region, so their answer is somewhat incomplete, but they do have an understanding of some basic population principles.

Food chains

As an extension of the knowledge they gained in the population unit, students demonstrated their own understanding of the checks and balances in a natural ecosystem by designing a food chain composed of two herbivores and a predator using a STELLAStack, teacher-designed simulation (see Figure 2). They designed their animals by selecting from a palette of skulls, legs, and various behavior traits such as parental care and the strength of herd behavior.

Before designing their animals, the students set goals describing how their system would behave. In this case, the goals were in terms of population size fluctuations for the three different animals over a 30-year period. The students then worked toward their goals, designing, running a

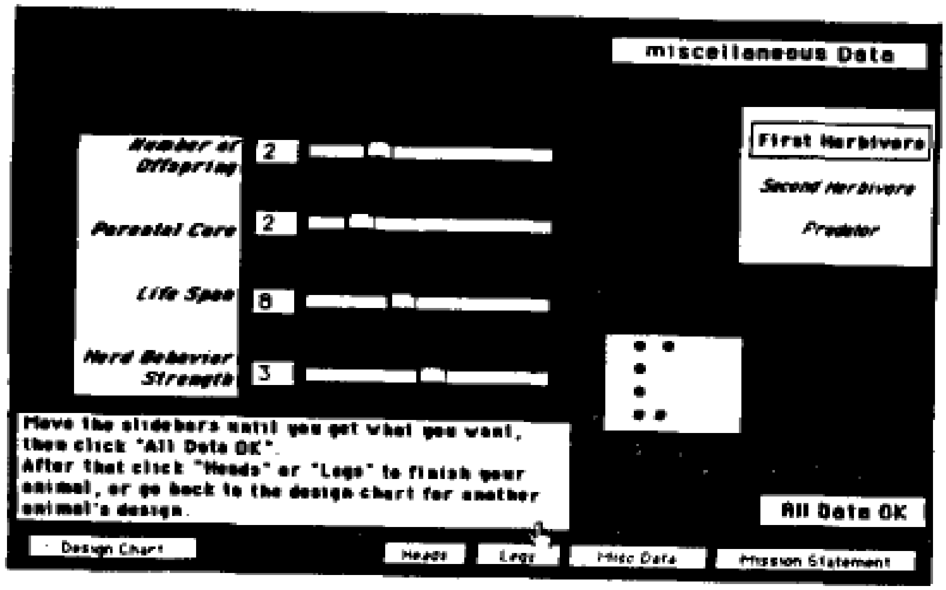

Fig. 2. STELLAStack screen for a teacher designed simulation of a natural ecosystem comprising two herbivores and a predator

STELLA model of the three populations, redesigning their animals, and rerunning as they saw fit, until they achieved their goals. Throughout this progression of designing, running, and redesigning, the students had to compromise on the efficiencies of their animals (for instance, too efficient predators wipe out all their food and die off themselves). This served to recapitulate the natural selection processes that may have resulted in the slightly inefficient animals that populate the world today.

Microbiology

Instead of hearing from a teacher or reading in a textbook that antibiotics kill bacteria, students simulated, with a teacher-built model, the role of a doctor discovering which minimum dose of penicillin is most effective in curing a case of strep throat, by changing dose levels in a "patient." Instead of laboring through the immune response, with its long list of names and actions, students worked toward an operational understanding of the relation between their bodies and pathogens by changing antibiotic levels in an infected person's body and, in a separate simulation, determining when a community should be immunized—before or after the flu hits town.

Land use

Students acquired a fuller understanding of land use conflicts by designing a new state park within a budget and prescribed mission (i.e., students predetermined what the attendance and environmental quality of their own park should be before they began designing). After researching the conflicts that arise in national park and wilderness area management (specifically the Grand Canyon), students designed a new state park, again using a STELLAStack, teacher-designed simulation (see Figure 3). Their

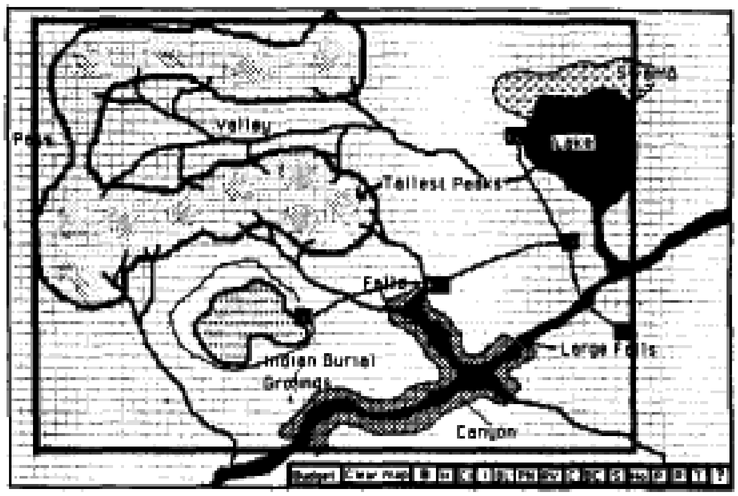

Fig. 3. STELLAStack screen for a teacher-designed simulation that enabled students to explore the environmental impacts of different designs of a new state park

designs were then subjected to a teacher-designed "use model," which predicted the environmental degradation and annual attendance over the next 30 years. If the results did not fit within the mission statement they had created at the outset, students modified their designs.

In other words, students learned much of the same content as would be found in a traditional science classroom, but they learned it by researching the topic, then thinking, hypothesizing, and designing components. In addition, they learned the content not as disparate parts, but as an entire system of relations and feedback loops.

Benefits of the interactive, simulation-based approach

We utilize a teaching style that transfers the focus of the classroom from the teacher to the student. Students shift from being passive consumers of information that need only be remembered until the next exam, to being active participants in the acquisition and utilization of knowledge. In this environment they become intrinsically motivated to extend the information they have learned. Assigning two or three students to a computer allows them to teach themselves and each other as they work through science projects. An important benefit for teachers is that the learning environment is exciting and rejuvenating for both teachers and students. When students have a good time while learning, classroom discipline problems drop and teachers have more time to spend with slower students. In an open-ended survey, 70 percent of the students in our classes called the systems projects the "best part" of the school year.

We think this approach is especially appropriate for at-risk students, such as minority and special needs children. They become active participants in their education, not passive vessels. Although our data, as yet, are preliminary, we have seen the motivation and success of consistently low-achieving and special needs students increase dramatically when they participate in these activities. Science teachers from a neighboring Tucson school with a high minority population, after observing an example of our classrooms, immediately asked for in-service education from us.

Our ultimate goal is to develop a society that can make more responsible decisions. A current buzzword in education is critical thinking. Thinking critically is not enough; people need to be able to know how whole systems and interdependencies work, and how to live better as a result of that knowledge. If we can have people, early in their cognitive development, explore and accept systems thinking and circular causality, then front-line publicists like Donella Meadows can relax the battle against the “prevailing paradigm” and give more attention to debating competing models within a shared world view. Perhaps then we could begin to address fully the big systems problems facing our species today.

References

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