the Creative Learning EXCHANGE

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THE FUTURE OF SYSTEM DYNAMICS AND LEARNER-CENTERED LEARNING IN K-12 EDUCATION, Part II

A Report from the Planning Meeting in Essex, Massachusetts, June 23 - July 1, 2001

Prepared by Debra Lyneis and Presented at The International System Dynamics Society Conference, Palermo, Italy, July 2002, by Lees Stuntz and George Richardson

INTRODUCTION

In June 2001, a group of educators and system dynamicists met in Essex, Massachusetts to envision the future of system dynamics in kindergarten through twelfth grade (K-12) education in the United States. System dynamics is a disciplined way for students to understand the causes of change in the ubiquitous systems that surround us. At the Essex meeting, our purpose was to appraise our experience thus far and build on it to articulate a clear vision of what an education based on the principles of system dynamics could provide to students and their communities. We developed a strategy to realize the vision and a 25-year plan to implement that strategy. Part I of the report was published in the winter issue of The Exchange; Part II completes the report.

THE STRATEGY TO REALIZE THE VISION

Fundamentally improving K-12 education through system dynamics is an enormous challenge, best approached in measured steps. The task is to create something new out of what is available.

Early experience indicates that the growth of K-12 system dynamics will follow the "infection model," a process also described as spreading by "word of mouth" or "grassroots." The systems approach is introduced into a school through the curriculum. It starts when a few innovative teachers are drawn to the approach because they see that it can benefit their students. As these teachers experience success in their classrooms, their colleagues try it also, and the idea slowly spreads. The stock of teachers using system dynamics grows as teachers perceive its need, try it, observe its benefits for their students and voluntarily change the way they teach. The strategy is to foster the steady "infection" of system dynamics within schools until the change gains widespread acceptance and sustains itself.

To initiate and sustain the strategy it is essential:

- *To determine what K-12 students have been able to accomplish in system dynamics so far and build on that experience to outline what students could plausibly achieve.* Currently, only a few schools across the country have embraced the system dynamics approach, and none of these has yet achieved the level of the envisioned ideal school. To effect change, it is important to have a plausible, clear, explicit description of the end product for students.

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MURDOCH MIDDLE SCHOOL, Part III

By Dan Barcan

The summer after the Murdoch Middle School's second year, a year that had ended, surprisingly enough, with children in tears at the prospect of having to leave for two months, the teachers convened in Burlington, Vermont, to continue their training. Two professors at Burlington's Trinity College (the College has since closed its doors), John Heinbokel and Jeff Potash, had invited the faculty to join their summer professional development sessions on systems thinking and dynamic modeling in K-12 curriculum. Nearly everyone went.

During the week the staff spent together at Trinity, they pushed themselves beyond where they had gone the previous summer in their dynamic modeling training. The first training had helped five teachers improve a specific skill; this one engaged a group of ten or twelve in deep conversation about how things really worked at the school, using the tools of system dynamics to improve the dialogue. Together, with the professors serving as facilitators, they created

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UPDATES…

Murdoch Middle School

Murdoch Middle School has just started an activities program that runs almost two hours on every Wednesday afternoon that we do not have an early release day. I have chosen to try to do something with systems to allow students to have an opportunity to do some systems projects that are a little more in depth than they might get to do in the classroom during regular project time. I just started my second session and will have one more session before the end of the year. My introductory day introduced use of BOTGs to look at a story and choose a stock and the appropriate flows for a simple paper model.

Janan Hamm

GIST Project

"I didn't know they could do this…"

As we work with teachers to implement Systems Thinking and Dynamic Modeling in Glynn County, Georgia, one of the most common positive responses we continue to hear is "I didn't know the students could do this." "*This*" can be any number of things: the class that is often sullen and silent springs to life as they participate in, discuss, and write about a physical simulation of cooperation and survival after a ship sinks. The math-oriented student who usually dislikes Language Arts is suddenly very interested in contributing to the creation of a whole-class Behavior Over Time Graph about a story they have read. High school students explore the responsibilities of leaders and individuals in a large crowd, while helping to create a STELLA model of Mob Anger from Shakespeare's *Julius Caesar*. Seventh graders using a STELLA model of Population become excited when they suddenly realize, through experimentation, that in order to help Third World nations, foreign aid must help them to decrease their birth rates as well as their death rates. Second graders verbalize their first comprehension that simple cause-effect explanations are not good enough to explain what they know about pine tree reproduction.

When teachers see students responding in positive ways that they have not seen before, they want to use more Systems lessons, and many are starting to implement Systems with less dependence on Waters Foundation Mentors, which frees up more mentor time to develop new lessons and reach new teachers. This is a nice reinforcing feedback loop that we are grateful to have the opportunity to participate in, thanks to the continued generous support of the Waters Foundation.

Also, in a quick personnel update, we are happy to announce the addition of Christine Dodson to our project. She has hit the ground running this year as a new mentor to replace Jan Mons, who retired last year. Jan was instrumental in getting the GIST project started in the first place; her vision of Systems-based student-centered learning will continue to thrive in Glynn County, and we wish her well and much success in her pursuits.

Steve Kipp

EDITORIAL

As the spring approaches (in some places more quickly than in others) it is a good time for all of us to be thinking about which lessons from system dynamics we want our students to have as legacies as they leave us. Which tools would you like them to have on their tool belts? What systems overview have you given them to help decrease the fear and anxiety that the media is intent on fostering? What will you need to do this spring to help your students next year? I welcome calls and questions, and would be happy to talk on the phone or via e-mail about your systems teaching plans.

Recently, during my trip to Glynn County in Georgia, where spring really *is* coming, Steve Kipp, Christine Dodson, and I got into a discussion about the use of adjectives in speech and writing. One thing I have noticed is that if you take comparative adjectives (like best and worst) out of your speech, you become much more precise about what you are communicating, and, perhaps more importantly, you stop comparing. You stop creating the winner/loser atmosphere that pervades our culture.

May you enjoy your crocuses and daffodils as well as your learning. Take care.

Lees (stuntzln@clexchange.org)

K-12SD Listserve

The K-12SD listserve has changed servers. It now resides at the same location as the Creative Learning Exchange website. If you are not yet a member, please join us.

To subscribe: Send a message to listserv@sysdyn.clexchange.org with the line "subscribe k-12sd first-name last-name" as the only thing in the message's body (no footer, no signature, etc.) The subject line is immaterial."First-name" and "last-name" should be your first and last names, for example, "subscribe k-12sd Lees Stuntz"

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Essex Planning Meeting

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- *To develop extensive curriculum materials of demonstrated benefit that are ready for teachers to use.* Until now, teachers have had to create their own classroom materials. It is important to learn from the most effective lessons and develop more materials across the range of grade levels and disciplines. Since a shortage of good materials is a constraint, this is an early priority.

- *To focus on teacher training and support.* Teachers need training in system dynamics and on-going support as they use it with their students. To this end, it is necessary to develop effective teacher-training materials and train the teachers who will then be using the materials to train and support others. We need to build on our past system dynamics training experience and broaden the cadre of teacher-trainers because this is another bottleneck. Our goal must extend beyond simply transmitting computer-modeling skills, however. In the process, we must help teachers become systems thinkers too. Training and support are equally crucial for school administrators.

- *To maintain high standards of quality for curriculum materials and training* because an erosion of standards will undermine credibility and sustainability. It will be important to enlist the help of system dynamics professionals throughout the process for help with quality control.

- *To acknowledge that system dynamics can be difficult to learn at first* because it requires looking at things through a new frame of reference. It will be up to skilled teachers to devise ways to make system dynamics accessible to a broad audience. Meanwhile, we all need support and patience.

- *To assess student progress continually* in order to demonstrate that a systems education can deliver its claimed benefits. Assessment will also be important for the on-going evaluation and refinement of curriculum materials and teacher training. It will be necessary to engage experts in assessment because we do not currently have that expertise and because we can benefit from their feedback.

- *To let students be our ambassadors.* Students who have studied system dynamics can eloquently and enthusiastically express what they have learned. They always impress adults with their poise and depth of understanding of complex issues. Keeping students out front not only wins converts but also reminds all of us that students are the reason we pursue this.

- *To recognize that system dynamics does not stick if it is mandated from above or pushed too fast.* Teachers, administrators and communities need time and patient support to digest and accept these ideas at their own pace.

- *To value the vital role of administrators in effecting school change.* A supportive administrator can encourage and facilitate the spread of system dynamics within a school. This is especially true if the administration embraces the principles of organizational learning, creating a climate of continuous improvement, collaboration, and creative risk-taking.

- *To engage local communities in their schools.* Everyone benefits when schools, community members, businesses and other institutions work together to improve K-12 education. Outside initiative, feedback and support are vital needs.

- *To work with the growing number of educators around the world who are also introducing system dynamics into their schools.* We can learn from one another.

- *To acknowledge that any effort to change K-12 education will naturally engender resistance.* It is necessary to use the tools of system dynamics to look for leverage points and work within the system rather than against it.

WHAT CAN STUDENTS DO?

Based on early experience in classrooms, teachers are frequently surprised that students can do more than they would have expected. Students have demonstrated that they can do the following: (Note: These are specific cumulative system dynamics skills, but they are all used to deepen understanding of topics within the context of the current curriculum. Examples of actual lessons are briefly described in Appendix A. Grade levels and activities may shift as we move forward and learn more.)

Kindergarten

- Recognize patterns of change
- Identify accumulations
- Participate in classroom simulations, games

Grade 1

- Understand behavior over time graphs
- Understand a basic stock/flow diagram with one stock
- Plot data on a line graph from an activity
- Discuss causes of change
- Discuss delays

Grade 2

- Compare slopes of behavior over time graphs with different rates of growth
- Graph stories from literature with behavior over time graphs
- Discuss feedback and simple causal loops
- Identify balancing and reinforcing feedback loops
- Discuss patterns of exponential growth

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Grade 3

- Use a simple system dynamics computer model with classroom simulation and graphing activity
- Discuss the concept of a model as a representation of reality
- Use behavior over time graphs with two variables and infer causality
- Create simple feedback loops from stories
- Analyze graphs from newspaper articles

Grade 4

- Build one-stock linear models in teams with direction
- Make predictions before running a model
- Generate behavior over time graphs independently in many applications
- Distinguish between linear and exponential growth patterns in graphs and structure
- Recognize oscillating patterns

Grades 5 and 6

- Build one-stock linear and feedback models independently
- Explore the relationship between structure and behavior
- Explore transferability of structure; notice that the same basic structure appears in different contexts
- Draw multi-loop causal loop diagrams independently; label balancing and reinforcing loops
- Use graphical functions to capture non-linear relationships, with direction

Grades 7 and 8

- Use/construct 2- to 3-stock models
- Apply simulation to the consideration of global issues
- Discuss how loop dominance affects behavior
- Use behavior over time graphs and causal loop diagrams to organize a term paper and presentation
- Use graphical integration to understand simulation
- Use pencil simulation to understand *dt*

Grades 9 and 10

- Explain functioning of behavior segments of larger models
- Suggest and justify policies based on models using writing and presentations
- Apply an existing simple to moderate level model structure to another discipline or problem; recognize and transfer learning across disciplines
- Predict the behavior of the system by looking at the structure
- Use modeling language to describe and explain the dynamic structure in news articles
- Use group model building to collaboratively address real world problems

Grades 11 and 12

- Identify a real community issue and apply system dynamics to its solution
- Present results and insights to an audience outside of school
- Advocate policies based on analysis and insights
- Re-examine policies and models in response to criticism

And More…

Above, we have listed activities that students are actually doing now in pioneering schools across the country. They represent only a beginning. Following are additional system dynamics threads that we also envision for students. Students will:

- Study economics in the framework of system dynamics, beginning in elementary school with the study of bank balances and money management and progressing through the grades to the study of national economic policies.
- Use models of growing scope, starting with a very simple structure in younger grades and adding complexity as the depth of study of a topic increases through the grades. The study of revolutions and social movements is an example.
- Study a set of exemplary generic system dynamics models that address significant problems and illustrate the general characteristics of complex systems. (These are "gem" models.) Advanced students will also study the classic system dynamics literature, e.g. *Introduction to Urban Dynamics* by Alfeld and Graham, *Urban Dynamics* by Forrester, and more.
- Welcome outside expert review and criticism of their work as a way to learn from mistakes and grow – also as a guard against complacency with internal quality.
- Develop the ability to read and evaluate the models of others.
- Study and learn from flawed models.
- Develop a culture of raising quality by reviewing others' work and learning how to give and receive constructive criticism gracefully. Make error creative.

THE PLAN

With a vision and a strategy in hand, the work of the Essex meeting turned to developing a 25-year implementation plan. Where do we start? What steps must we take to bring the vision to fruition? What resources will we need? Our goal was to develop a plausible, practical plan to guide the effort. Although the details of the proposal may continuously evolve, at any point in time it is important to have a clearly articulated goal and plan for achieving it.

Several tools aided the process of identifying necessary resources and plotting their growth over the next 25 years. A spreadsheet matrix displayed the specific needs for each resource year-by-year. A spreadsheet model computed costs based on those projected needs, and a PERT chart provided a visual representation of the matrix. A preliminary system dynamics simulation model examined how system dynamics innovation spreads within schools; its purpose is to identify leverage points and obstacles to progress.

Resources

Infusing system dynamics into K-12 education is a process that will start on a small scale and require increasing outside resources to support it over the next 25 years until it can eventually sustain itself in school systems. Following is a list of the required resources. In systems parlance, these are the stocks, or accumulations, that will need to grow and be monitored over time.

- **People Actively Involved**
  - Students
  - Teachers
    - Using SD curriculum
    - Developing curriculum
  - Professional system dynamicists
  - School administrators
  - Evaluators
  - Content area experts
- **Training Programs**
  - Summer and in-service training programs for teachers and administrators
  - Pre-service training (teacher education programs)
  - Training materials
  - On-going support for teachers and administrators
- **Curriculum Materials**
  - Teaching materials infusing systems thinking/system dynamics concepts and tools throughout the K-12 curriculum
    - Single discipline
    - Interdisciplinary
  - Administrative models and materials
  - 'Gem' models – elegant classic generic system dynamics models illustrating systems principles
- **Assessment Capabilities**
  - Professional assessment resources (schools of education, etc.)
- **Getting the Word Out**
  - Promoters
    - People who raise money
    - People who build networks
  - Publicity materials
  - Strategies for overcoming resistance
  - Citizen Champions
- **Project Management**

The Matrix

The resource list became the spine of a matrix that plotted specific needs over the next 25 years in each area. This was a challenge because all of the strands are intertwined, interdependent. It soon became apparent that the two most pressing needs are to develop quality curriculum materials and to establish good training materials and programs for teachers. Initial efforts will focus on these because success in all other areas depends on them. These are highlights of the discussions:

Curriculum Creation, Review & Refinement

The first task, already underway, is to sort and improve the materials currently available through the Creative Learning Exchange and to establish processes for the creation and review of new materials. Moving forward, curriculum materials will be developed in two ways. Continuing the current practice, lessons will be created, written and tested by teachers and mentors in their own classrooms. Curricula will also be developed in more intensive summer curriculum writing workshops involving teachers, subject area specialists and system dynamicists. These curriculum materials will be tested with students during the school year, refined the following summer, and field-tested again before publication. An example would be developing high school biology units that teachers could use separately or as a complete course. (Because all high school students study biology, it is a high- leverage starting point. There are many other such points in the current K-12 curriculum.) Writers and editors will assist in preparing both the site- and workshop-generated materials. There will be on-going review of the materials and the development process. The goal is to build a comprehensive K-12 curriculum.

Costs associated with curriculum development include released time and remuneration for teachers who write lessons during the school year, plus the expenses of conducting the summer workshops, including stipends, travel and housing costs for participants. (See Appendix B for a more detailed outline.)

Training resources

Proper training and support are crucial needs. Training consists of developing and refining training materials, training the trainers who will use them, and actually setting up training opportunities for teachers. Some training, especially introductory sessions, will continue to be held in-service, in schools, conducted by local mentors and teachers. There will also be a need for more intensive and advanced programs at system dynamics teacher-training centers. Such a center could be housed at a college or university where system dynamics experts and teachers could prepare and sponsor summer training workshops and ongoing teacher support throughout the school year.

Costs associated with training include teacher and trainer stipends and expenses for summer workshops, plus the costs of establishing and staffing several national training centers over twenty-five years. (See Appendix C.)

The Development Office

A professional development staff, part time at first, will raise the funds necessary to support the program. The first need in this category is the seed money to establish a development office and hire a professional to run it. The staff will create publicity materials and explore funding resources. In the outlying years, as K-12 system dynamics spreads and demonstrates it effectiveness, the need for outside funding will diminish when local school districts begin to absorb their own costs.

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Laboratory schools

These are schools at which many of the curricular and training ideas will be tested and implemented. Each laboratory school needs:

- One mentor – a full-time teacher with systems thinking and system dynamics expertise who helps colleagues learn and implement skills in their classes.
- Released time for several classroom teachers to collaborate, develop curricula and mentor fellow teachers as the need arises.
- Funds for curriculum and administrative support.
- Extensive summer training for classroom teachers and administrators.
- Availability of professional system dynamics expertise.
- (There is overlap among curriculum, training and lab school categories.)

Helpers

This includes teacher mentors in other schools across the country supported by system dynamicists as a resource to help sustain the quality of their work. Experience, primarily through the Waters Foundation, has shown that teacher mentors are a high leverage means to train and support teachers within schools.

Assessment resources

It will be essential to assess student learning to inform our continuous improvement and to demonstrate the benefits of the systems approach to others. Professionals will devise and administer appropriate assessment programs with the guidance and oversight of experienced teachers and mentors. Graduate research on the effectiveness of system dynamics curricula will also be encouraged. Assessment will be conducted in the laboratory schools and at other schools. Assessment is a challenge because, although we believe that students gain a deeper understanding of the current curriculum, many of the broader skills and perspectives also gained through systems education are not readily measured on today's standardized tests.

Project Management

Initially, the Creative Learning Exchange, a non-profit organization, will provide central coordination and financial management. Another structure may emerge as needs expand.

THE CHALLENGES

System dynamics and systems thinking hold great promise for fundamentally improving K-12 education at a time when schools are under intense pressure to do a better job preparing students to thrive and contribute in a rapidly changing global economy. System dynamics can revitalize schools and unify the curriculum. It can prepare students to deal effectively and compassionately with dynamically complex social, political, environmental, and economic problems facing them.

A clear vision and a strong partnership among committed individuals with diverse backgrounds and skills will move us forward. But the path will not be straight and easy. An early challenge will be to widen the circle of people who are involved so that the work can be accomplished in a timely way. Another challenge will be to maintain high standards of quality in curriculum and training as we grow because diluted quality can discredit and derail any progress. To avoid eroding quality, we need to nurture a culture of continuous improvement and carefully monitor the pace of growth.

A further challenge will be adapting our programs to the needs of the market. Teachers drawn first to the system dynamics approach will be the innovative teachers who are already seeking change. They are easy to win and tolerant of the uncertainties that accompany pioneering. The challenge will be to move beyond these early adopters and reach the larger majority of teachers who will change only when they are convinced that a program is established and successful. We will need to be mindful of the "chasm" between these two groups – all at a time when standardized testing appears to be pressuring teachers to teach an increasingly proscribed curriculum.

A final challenge, of course, is funding. Effecting change in schools is an ambitious undertaking. Although this effort will start small and grow slowly, it will still require substantial financial support. There are innovative teachers and administrators across the country who are ready for change, but local school budgets are stretched thin just trying to meet day-to-day challenges; there is little money left to break free and try something new. Systemic improvement in K-12 education will need the help of reform-minded citizens and institutions willing to support these innovators in new ways. It is an investment in our future. The time is now.

End of part 2. *The first half of the Essex report was published in the Winter 2003 newsletter (Volume 12, Number 1). It is available free of charge in its entirety, including appendixes, from the CLE website, catalogued under Implementation as IM2001-07FutureOfSDEssex.*

Participants at the meeting in Essex were: Dan Barcan, William Costello, Diana Fisher, Jay Forrester, Scott Guthrie, John Heinbokel, Debra Lyneis, Jim Lyneis, Jan Mons, Jeff Potash, Rob Quaden, George Richardson, Barry Richmond, Lees Stuntz, Alan Ticotsky, Larry Weathers, and Ron Zaraza. They were assisted by Peter Bloniarz, Davida Fox-Melanson, Gary Hirsch, Tim Joy, David Packer, Pat Quinn, Eileen Riley, Khalid Saeed, Peter Senge, Stephen Stuntz, Ginny Wiley, Sherry Immediato and members of the SoL community.

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Murdoch Middle School, Part III

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copious loop diagrams in an attempt to capture the dynamics of the subjects that, though they were not strictly academic, interested many of them the most: Why didn't all kids do their homework? How come the bathrooms always looked horrible? What was the best way to keep students from hitting each other?

Nearly everyone who attended remembers the week as one well spent—a time when they thought hard all day, about topics directly related to their jobs, with the aid of their colleagues. While there was little, if any, formal instruction or practice in actual dynamic modeling, the more pencil-and-paper (and Vensim) approach did not bother anyone.

Returning to Massachusetts, the seventh and eighth grade team began to plan a project that incorporated much of what they had worked on in Burlington, but that was directly based on yet another training session they had attended. This project was sponsored by a local environmental advocacy group and had as its main assignment the creation of an "action plan" to help solve an environmental problem. Never mind that the team had recently finished a week—the Trinity College session—in which they had spent hours and hours trying to find reasons why kids didn't bring pens to class. Somehow, the same group of kids and teachers was going to clean up a nearby lake, ensure the opening of a town bike trail, and fight a proposal to enlarge a local highway. It would be, to say the least, a tough project to run.

Why did this complicated project seem so attractive? For one thing, the training, support, and materials were free. For another, teachers from the local district middle school were also at the training, and the charter school's teachers had made tentative plans to have the students from the different schools collaborate in some way. Since relations with the district were always iffy, at best, this chance seemed like one not to be passed up. And the whole thing supported the state curriculum frameworks. But really, it was what those required action plans implied: Looking for causality. Leverage. Feedback. Archetypal behavior. Their summer had prepared them perfectly.

What they had forgotten, of course, as they planned out the different assignments for the project, which went by the name "Earth Force," was that creating even a small set of loops had required quite a bit from them. They had five or six adults working on each one. An experienced university professor guided each discussion. They spent hours each day, over the course of a week, settling on loops that they all considered fairly representative of the problem in question. And, perhaps most importantly, each of their loop sets was about a problem that they each had already spent time thinking about, nearly every day. What teacher doesn't walk around with a head full of data and theories about why his class doesn't do X, or won't stop doing Y? All they had to do, really, was get their ideas onto the white board, then argue about how to link it all together.

The kids, on the other hand, were going to start from scratch. Each had collected a sheaf of newspaper articles about various environmental topics over the summer (those who had done their summer homework, anyway), and early in the school year they scanned the articles for hints about causality and feedback. From the meager bits of information they found, they cobbled together loop sets.

The topic—how to make loops, specifically—had fallen into that pedagogical netherworld in which a class can simultaneously say, "I don't know how to do this," and "We already did these." Determining the veracity of statements such as these is always a slippery matter, but hearing them in a classroom is a pretty good sign that you have not taught something effectively, and that students are about to put forth a halfhearted effort.

Disappointed with the entire project, the teaching team set causal loops aside for a while. Sure, they thought, we can get kids to draw loops, but how do we get them to draw loops well, to understand them well enough that they care about the quality of the product? Perhaps, they said, when we have more time. When we understand it better, so will they. We wish, they said, we had someone who could work on preparing materials and training us to teach this stuff. And wouldn't you know it? Their wish came true.

...We wish, they said, we had someone who could work on preparing materials and training us to teach this stuff. And wouldn't you know it? Their wish came true.

The following year, the Waters Foundation[1] provided funding for one teacher at the school to spend one day each week working on system dynamics-related curriculum. By now, Sue Jamback had been able to sense that her staff was being run a bit ragged by creating everything themselves. She advised that teacher—me—to stay away from the school on my "Waters Days." Instead, the best idea, we decided, was to carefully pick through the materials that existed on the Creative Learning Exchange's web site and select some to bring into the school.

[1] www.watersfoundation.org

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Murdoch Middle School, Part III continued from page 7

It wasn't long before the strategy paid off. Early in the school's fourth year, during a project on cartography that included a few days studying early civilizations, I brought in a model, downloaded from the CLE web site, of the last days of Mohenjo-Daro[2]. After locating it, which was relatively easy, I spent the better part of two days—two weeks, that is, using one day per week—understanding its dynamics and preparing materials to go with it. It worked very well. The class—and another studying Mohenjo-Daro—enjoyed using the model, even though they didn't get to each play with it as they had with the newspaper model the year before, and they recognized the dynamics at work.

Two classrooms, though, was not enough. Slowly, as I found more useful products to bring in and share via mailbox, e-mail, or team meeting, the use of the tools spread out into nearly every classroom. A project in which students followed different equities to learn about financial markets and macroeconomics had gone very well two years earlier, but the teachers improved it by adding a week in which students modeled the compound growth that convinces us all to sock away our money in mutual funds. The resulting graphs made nearly every seventh and eighth grade student a billionaire, since no one was able to build the balancing process that bursts stock bubbles. But it was the winter of 1999, so perhaps that didn't seem so important. After we recovered from being blindsided by the confusion that ensued when there were two completely different things called "stocks" in the same unit, the kids got the idea.

During the same project, kids participated in something we called "TulipMania," a sort of trading pit for tulips, designed to simulate the speculative craze surrounding blighted tulip bulbs that gripped Holland in 1637. After yelling and screaming and buying and selling in a frenzy for about forty-five minutes (the teachers played the part of "demand" and bought tulips of various colors according to demand graphs that roughly mimicked the real mania), the class was able to talk through the loop sets that represented ever-growing demand followed by a crash.

A different unit, in which students studied Westward Expansion in the United States during the nineteenth century, was built entirely around a wall-sized behavior-over-time graph which showed, on its Y-axis, the percentage of U.S. land controlled by Native Americans (admittedly, a poor translation of history, since different tribes had very different beliefs about whether land could be "controlled" at all) and the percentage controlled by white settlers. Of course, the two numbers changed drastically over the hundred years in question—one line kept going down, and the other kept going up. Students then placed events along the timeline of the X-axis as they decided that those events had had some effect on who had controlled the land. While they spent a good deal more time researching the different events than doing any dynamic modeling (we had learned something from Earth Force), they were able to see how a series of relatively small—if routinely horrific—events led to an enormous change. Many teachers used behavior-over-time graphs in a variety of ways in their history classes.

And seventh and eighth-grade students studying physics spent a day working with a series of small models that demonstrated position, velocity, and acceleration[3]. Using these models—no larger than one or two stocks—they solved simple physics problems about when one car would pass another, when a rolling ball would reach the bottom of a ramp, or when a truck would reach a certain speed. In a fifth-sixth grade classroom, students used a flight simulator to better understand the novel *The Giver.*

With nearly every student enjoying some exposure to systems thinking and system dynamics, the school was able to find ten kids, representing all grade levels, to send to the first annual DynamiQueST, held that year at Trinity College. That small cross-section of students—certainly not all would have been able to manage it—demonstrated expertise in constructing models or stock-and-flow diagrams, drawing loop sets, and facilitating systems thinking-based games.

The kids involved were not those who always performed at the highest levels back at school.[4] Reflecting on this fact after the weekend had passed, and wondering about what it was that led a student to show a talent for systems thinking and modeling, the teachers began to wonder about why they had not achieved any of the goals the school had set for itself. Think about that for a moment: the school had listed specific goals regarding the mastery of different systems thinking and system dynamics tools for the grant application, and after a year of good faith effort, wasn't close to meeting any of them. Certainly, they were moving towards many of them. But the levels they had set for themselves—ninety percent of the student body being competent at looping, or finding leverage, or drawing operational diagrams—seemed ridiculous when compared to where the school actually was.

But where, exactly, were they? No one knew. Sure, teachers knew, watching one fourteen year-old say to another at the Trinity College event, "There's got to be a better way to solve this…" that some of them had "arrived." But they had spent hundreds of hours over the past few years creating and modifying tools to assess, for example, writing—something all of them were able to do competently. How exactly would they create analogous tools for dynamic modeling?

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[2] Available on the CLE website—clexchange.org—catalogued as CC1994-08MahenjoDaroSim

[3] Also available at the clexchange.org. website, catalogued as CC1997-01LetItRollRampModel

[4] See an article on this topic ("System Dynamics and Student Leadership," Barcan) on the website, in the Fall 2001 Newsletter (volume 10, Number 4).

On one occasion, teachers created a rubric to assess causal loop diagrams. Taking the notes from different training sessions, they tried to determine what characteristics made a loop correct. When two advanced students created a wild page full of circles and arrows to explain the systems at work in the book *Native Son*, their teacher happily handed them the rubric. “OK,” he said. “Nice start. Now, get revising.” They revised. Weeks later, at DynamiQueST, a nationally recognized system dynamics expert wondered aloud who in their right mind had asked those two girls to change their original loop set. It was probably the best feedback the faculty ever received about an assessment tool, but it pointed to a major gap in what they were trying to do.

Without the ability to accurately determine what success even looked like, they were not going to be able to measure success, and, more importantly, they were not going to be able to help students achieve it on any sort of regular basis. What they could have measured, though, was teacher behavior. It would have been easy to see if each faculty member had, say, used a working model in at least one lesson, or if everyone had assigned students to create at least one loop set. But it never became an explicit goal.

In fact, the staff didn’t do any of the normal things they did with other sorts of school work they assigned. They didn’t observe each other teaching systems concepts, or create models that students could try to copy or emulate, or even talk about what would have made one model better than another. They didn’t require a piece of systems thinking or system dynamics work to go in the portfolios.

How did they miss these things? For one, they tended to see systems thinking and system dynamics as something separate from the rest of the curriculum. While students received careful feedback on, and moved towards mastery of, basic physics, the history of Mohenjo-Daro, or the symbolism in *Native Son*, they hadn’t made much progress at systems-related skills. When teachers encountered situations in which students understood a concept—say, how bills become laws—but not the systems tools—say, causal loop diagrams—that they had used to understand the concept, they moved on.

But systems education was in the school’s charter, right? The school was bound by law to teach it. The state would be checking for it. All true, but there wasn’t anyone at the state’s charter school office—staffed by three people, who had the responsibility to monitor roughly twenty-five schools—who really knew what they ought to look for to know they were seeing “systems thinking and system dynamics” in a school.

And with no one looking carefully over their shoulder as they attempted to move from a situation—the first few years—in which every failure was chalked up to the novelty of the entire enterprise, and every success celebrated as one might the discovery of a new element, to one in which they would be measured against their own past performance, the teachers balked. “Honestly,” says Leah Zuckerman, “we never really brought any pieces of student work [in the area of systems thinking/system dynamics] to meetings. Since this was the area where we were weakest, it would have made sense to help each other more.”

What that seems to tell us, then, is that despite their lofty student goals, the staff had created a system that would spread systems education, even integrate it, but would not ensure its quality. The goals, in fact, were the only things that spoke to the actual quality of the outcomes. The other parts—my focus on locating and disseminating materials, the exclusion of systems education from the normal support and feedback channels the staff had already built for the rest of the teaching—all made for a place where everybody would get systems, but no one could vouch for exactly how well they would get it.

Maybe such quality can come only from more experienced school mentors training new ones about how to lead others to learn about systems thinking and system dynamics, and maybe organizations such as the Waters Foundation or schools that have already learned to teach systems well can lead the way here. Either way, learning to measure how well we are teaching, and how well students are doing what we ask is as important when we teach systems thinking and system dynamics as when we teach anything else, and maybe more so.

This article, catalogued as PH2003-01MurdochMSIII, is available free of charge at clexchange.org

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Physics Simulators Available

A set of physics simulators based on System Dynamics models is available as a free download. These simulators, described in an article in December’s issue of *Science Teacher* magazine, cover three topics: Heat Flow in the Home, Travel Around a Curve, and Collisions.

The simulators can be downloaded from the web site of the Vermont Institute of Science, Mathematics, and Technology (VISMT), the organization that sponsored their development. I was the principal developer.

The specific link is: http://www.vismt.org/heatflow.html I’d appreciate any feedback on these simulators. Thanks.

Gary Hirsch gbhirsch@attbi.com

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Fun at DynamiQue*ST* 2003

May 9, 2003 9 a.m.–3 p.m.
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