the Creative Learning EXCHANGE

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ST/DM Conference June 25-27

The weather, the location, and the attendees conspired with the speakers at our fourth biennial conference to make it a memorable experience for all. Skamania Lodge housed the conference with good food, and patient and attentive service, as well as a spectacular view over the Columbia River gorge. If anyone was "conferenced out," there was always a comfortable chair in which to sit and contemplate the awesome spectacle of nature.

Our two keynotes, by Dr. Jay Forrester and Dr. George Richardson, were, as usual, thought-provoking and inspiring. Dr. Richardson emphasized little models which contribute to our insights about the world around us. He categorized insights into three categories, with their appropriate tools, utilizing several models: deficit and debt, oscillating spring, welfare archetype, and an urban model to illustrate insights which could be gained from them.

Kinds of Systems Insights

• Dynamic insights—Tool: graphs over time

• Structural insights—Tool(s): stock-and-flow/causal-loop diagrams

• Systems insights: "Dynamic behavior is a consequence of system structure"—Tool: computer simulation

Dr. Forrester reminded us that the information around us in our mental database is many times what we have in our written database, and that our written database is many times larger than our numerical database. Models based on all three are the most powerful. He also reiterated the Characteristics of Complex Systems—Transfer of problems between sectors, Tradeoffs between present and future, Resistance to most policy changes, Very few high-leverage policies, Transfer burden to the intervener, Cause and effect not close in time or space—and challenged us to expand on this list.

In addition to Drs. Forrester and Richardson, other presenters included a wide variety of teachers, both K-12 and college, independent consultants, and world renowned system dynamics practitioners.

A number of authors in the field shared their work with us. Andy Ford, who just published *Modeling the Environment*, Linda Booth Sweeney, co-author with Dennis Meadows of the *Systems Thinking Playbook I and II* (soon to be III), Janis Dutton, one of the co-authors of the to-be-released *Schools that Learn*, another in the Fifth Discipline Field book series with Peter Senge, and Barry Richmond, author of STELLA© software, all gave interesting and enlightening sessions.

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Building Sustainable Interest in Modeling in the Classroom: The Implications of the S-curve for Hooking New Practitioners in Schools

by Gordon Kubanek, ST&DM Conference 2000

"Your job is not to make them drink, your job is to make them thirsty."

System Dynamics has had a tough time breaking into High Schools. Like all good ideas, the most difficult part is convincing those who would most benefit that this new approach is in their self interest. When system dynamics is presented only as a computer based tool, most teachers will not try it. When we introduce systems methodologies in a way that focuses on the richer, softer and more human side, teachers start to simulate more quickly. Learning the "System Dynamics Way" is in fact introducing a changed relationship of learner, teacher and subject material. Systems Thinking can help to build a sustainable learning process. The three distinct parts of the classic learning S-curve that can be represented as "curricula" are: build ***Passion*** slowly, accelerate learning through ***Risk*** taking, and consolidate understanding by ***Reflection***. Using computer models is the goal because computers are the best tools for student controlled exploration and reflection. To bring practitioners on board, stealth should be used to *implicitly* train students and teachers about systems thinking.

"People don't resist change, they resist being changed."

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CONFERENCE ANGELS

Catalina Foothills School District

A huge presence at the conference, twelve teachers from Catalina presented 8 of our 45 sessions. Julie Guerrero and Mike Slootmaker presented a 3 1/2 hour beginners' double session, *Introduction to Systems Concepts and Tools*. Slootmaker and Jennifer Grant Prileson presented *Mining for Understanding, a Chemistry Unit.* In *Fifth Graders Create the Future*, Guerrero and Rebecca Stewart demonstrated how their fifth graders used systems concepts and tools to design, create, and explain their physical model of a future society. Tracy Benson and Joan Yates ran a workshop called *Play the Systems Way*. Kari Dean and Ron Michalak presented *Using Systemic Communication to Improve Problem Solving*, which showed how well students understand and operate in a complex system. Scott Suter, in *Systems Thinking in 5th Grade Social Studies*, addressed how system dynamics tools are used to help students better understand the world around them. Michalak and Laura Stepanek presented *Using Systems Tools to Construct Knowledge of Linear Equations*. Terri Fletcher and Bari Ross presented *Using Systems Concepts and Tools in Counseling and Guidance.*

Harriet Tubman Middle School

The Harriet Tubman Middle School in Portland, OR, also made a significant contribution. Seven of their staff presented five sessions. Michael Bishop presented *What Was the Impact of the Industrial Revolution on England, and Ultimately, on the Rest of the World?* which suggested that even as that Revolution precipitated radical change in society, we are on the brink of another revolutionary paradigm shift with the emergence of the Internet "Webolution." Judith Lampi presented *The Dynamics of Health Education*, which introduced how system dynamics is integrated into the health curriculum in an inner city middle school. Anne Boswell presented *Integrating Systems Thinking and STELLA Modeling throughout the Mathematics Curriculum.* In *System Dynamics and Systems Thinking: the Curriculum Strategies for an Integrated Approach*, Gaylen Brannon presented ideas from a 7th grade social studies and writing class that could be easily used for any subject/grade level. Mary Scheetz, Neomia Kendrix, and Marianne Hall presented *Developing a School-wide Approach to System Dynamics with Harriet Tubman Middle School Staff and Students.* The overall framework for grades 7-8 that includes introduction to basic concepts and tools at each grade level was presented, along with student and teacher examples of applications.

GIST

The Glynn County Schools contributed three sessions. Mary Jo Davis, Becky Hill, Jan Mons, Clelia Scott, and Eugenia Taylor presented *Systems Thinking/System Dynamics—The Fourth R?* In their K-5 program, they are introducing Systems Techniques as one of the basic fundamental skills. Judy Butler and Jan Mons presented *Scientific Method and Sixth Grade Physics.* Margie Varnadoe, Jan Mons, Mary Jo Davis, and Nell McCullers presented *Use of SD as a Tool for Collaboration*, sharing how they formed an administrative COHORT group to learn about SD and how to use it in school level decision making.

Carlisle Public Schools

Carlisle Public schools also presented three sessons. In *From Classroom Idea to Published Curriculum*, Debra Lyneis and Rob Quaden discussed the process and the actual K-8 curricula developed in Carlisle. In *Using Systems Thinking in School Administration*, Davida Fox-Melanson, Eileen Riley, and Alan Ticotsky discussed the progress and pitfalls encountered by an administrative team's first year exploring STITO (Systems Thinking in the Organization). In *Designing a Skills Matrix. Integrating Systems Thinking and System Dynamics into a K-8 School*, Quaden and Ticotsky described the process which has created a sequential, developmental matrix of activities and skills for students in grades K-8.

EDITORIAL

Welcome back, as the school year begins again. It is a gift to have renewal twice a year, from the natural world in the spring, and from our own school calendar in the fall. The school year brings new faces and new challenges, and for me, new resolves, since this is my New Year.

This is an issue devoted to the summer conference on the West Coast this past June. It is always both exhilarating and tiring to have the conference. Yet the exhilaration always wins out, since we leave each conference excitedly making plans for the next. Our next scheduled one will be in the summer of 2002, probably in New England. If you have any ideas for or about it, now is the time to tell us!

The abstracts and handouts from the conference are available on the CLE Web site (clexchange.org). We urge you to go online and see the wealth of experience which is represented there. Our sincere thanks to all particpants.

Lees Stuntz *<stuntzln@clexchange.org>*

Sustainable Interest in Modeling in the Classroom **continued from page 1**

The implied message of a System Dynamics classroom is a change in the POWER that the learner has. The student now holds more power than the subject or the teacher. The sustainable S-curve will be used to study teaching methodologies that will work in the LONG TERM. This paper will present experiences of the past two years experimenting in classrooms using the principles of systems thinking. Five strategies that have been practiced in three countries will be presented in detail. There will be examples of experiences in Canada, Australia and Singapore. The author believes that System Dynamics needs to focus on more than computer modeling. As a community, we need to push for changes in the overall teaching process and in the learning strategies that it, by its very nature, implies. A better understanding of this human dynamic would mean more practitioners would take up simulations as a regular teaching tool. A simplified version of the six-step modeling process of Goodman and Karash (1995) is used as the template for this process. The proposed model for a three-stage sustainable learning curve is below:

Learning Strategies to Build Sustainable Learning

In this paper five strategies to create a sustainable learning curve that have been used in three countries are presented. These techniques are NOT presented as THE answers but rather as tools that have been found effective in the situations encountered. What becomes more important than mere information is the changed attitude towards the knowledge acquired: "What can I do to develop deep, sustainable learning?" For of what use are schools if the students just learn to pass the exam and then forget what they have learned? Rather, following in the path of Peter Senge (*The Fifth Discipline*), educators need to be asking themselves ***"What can we do to turn our schools and classrooms into learning organizations?"*** (O'Neil, J.)

The strategies that will be presented are:

1. **Quality Learning**; using TQM principles in the classroom (Langford)
2. **Strategic Learning**; parallel to subject content, learning skills to "learn how to learn" are taught (Simpson & Nist); good examples are the "lateral thinking" tools of E. deBono (deBono)
3. **Brain Based Learning** (Dryden & Vos) & "Layering" (Nunley); use the latest in brain research and experiences gained with learning-disabled kids to improve learning for all kids; focus on differentiated tasks, student choice, and setting up tasks ahead of time with learning styles and multiple intelligences in mind. (Gardener)
4. **Simulation as Serious Play**; using simulations in the sense of computers supporting open ended exploration that values process, relationship, and personal meaning over the "right answer" (Schrage)
5. **Web Based Learning**; use the internet to allow self-paced, interactive courses so students can learn at their own pace (EDEN project)

When these strategies are used together in the systems structured sense of Passion – Risk – Reflection, any classroom can be turned into a mini "learning organization." In effect, there are at least three curricula which can be

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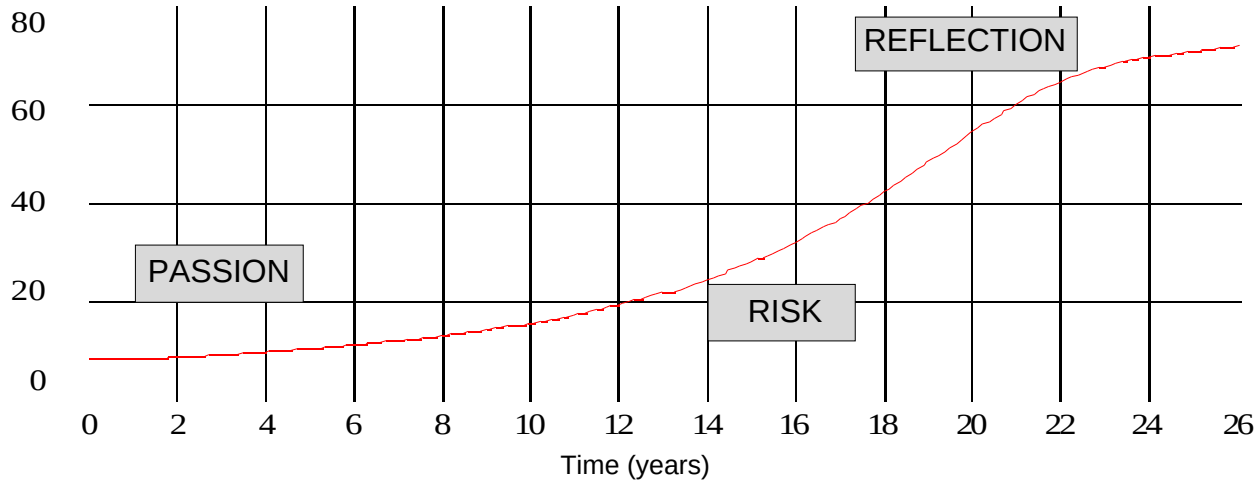
Graph for Successful Systems Thinkers



successful systems thinkers: success ——————————— success

"My company was an overnight success after 10 years of blood, sweat and tears."

Sustainable Interest in Modeling in the Classroom continued from page 3

matched to the three steps of the sustainable learning model outlined above.

Curriculum #1 is about creating **Passion; how to motivate**, build self-confidence and answer the career oriented question, "What's in it for me?"

Curriculum #2 is about creating an **atmosphere of Trust so learners Risk**, explore and increase the speed of learning new material, have more retention by active participation, and are taught strategies of "learning how to learn"

Curriculum #3 is about **Reflection and Metacognition** of the subject material; "Do I know what I know?", "Can I explain what I think I understand to somebody else?"

New teachers and student practitioners are "hooked" when they see the enthusiasm, success, and apparent ease at which teaching and learning seems to flow in a Systems based classroom. It is thus by example, by word of mouth and slow diffusion (Surry & Farquhar) that a new technology and approach to learning gains adherents. It is slow and takes persistence. But if you persist, the System Dynamics way of active, student centered learning with the computer will take hold in any class and in any school.

Work on the System—not in the System.

Case Study #1
Grade 7 Science Class, Alexandra, Australia – *Creating Passion*

While on a teaching exchange in Australia last year, I was initially frustrated by my inability to connect with the students. Their anti-authority cultural stance made any "pushing" to higher standards and quality of work counter-productive, and only created bad feelings and tension in the class. However Australian students and adults are enthusiastic to try out new ideas. This is exemplified by their expression "Give it a go, mate!" As a result, risk and innovation are supported. This allowed the author to quickly introduce new teaching models in his classes. The challenge in this small country school was clear: How can a teacher meet the learning capabilities and needs of a large spectrum of ability without boring some and frustrating others? While doing research on this question from a Systems Thinking world view, the author came across three approaches that started this school onto a path of more inclusive teaching. These approaches; Layering (Nunley, K.), Quality Learning (Langford, D.) and Multiple Intelligences (Gardener, H.), supported "sustainable learning" in the classroom by supporting the three step Passion - Risk - Reflection process. The focus in this case study is part one of the sustainable learning curve: building passion for learning.

You can't direct the wind but you can adjust the sails.

Step 1: Build Passion

For a non-Australian, the biggest shock was to experience the discrepancy between the students' ability, which was very high, and their desire to achieve high standards, which for most part was very low. (Australia has the second highest High School drop out rate in the Industrialized world.) The author told the students up front that, as this was my "Sabbatical year," I would be trying out new teaching methods ***with*** them and needed their participation and comments to make them work. This certainly got their attention. We decided together to study an entire unit in groups, and present what we had learned to the class with a handout. The questions and answers they wrote would become the unit test. Unfortunately this approach failed to include all learners. The weak students still did nothing, and if anything did even less and behaved even more rudely than before. In spite of this, there were great presentations by the highly motivated students, who really enjoyed taking charge of their learning. So I paused, taught myself, and tried K. Nunley's concept of Layering. Her approach works as follows:

A. Give students a range of work options at the start of the unit which is listed in three "layers", work options include all learning styles (visual, oral, kinesthetic, concrete operational or abstract), and the three levels correspond indirectly to the final mark (assuming good work quality) desired by the student.
B. The students then worked at their pace, alone or in groups, on the work requirements, with regular experiments to enliven the activities. My job was less to teach than to assist individuals when needed. It also gave students the chance to explain to others what they had learned, and become peer mentors.
C. Finally, the evaluation type and time was decided together with a "pre-test" given with answers and more time to identify and repair misunderstandings. The final test itself was "layered" so that the mark the students were striving for was clear. A variation I added was to reverse the mark weighting, so the layer 1 (easier) questions were worth more marks than the layers 2 & 3 questions. Every step of the learning process was clear ahead of time and had been decided upon together.

The sense of control this gave to the students turned the class around and, more importantly, it changed our relationship from one of confrontation to one where we were together moving towards a common goal.

Learned helplessness or learned optimism—the choice is ours.
- Martin Seligman

Step 2: Create Trust So the Students Will Risk & Not Be Afraid of Mistakes

Thank goodness this was an easier process than creating motivation. Australian students loved to risk, never

had problems with mistakes, and were used to working in small groups. The only problem was that some of them would openly say, "I'm too stupid to do this work or understand it," and then of course not even try! This too was a shock. It seemed that they were so insecure that to do hard work and then to "fail" was more dangerous than an open public admission of a low IQ!

Since I had managed to motivate them, the trick was to get them out of their comfort zone and extend themselves. So the students did an Australian version of Gardener's multiple intelligences (McGrath, 1995) test with an explanation and several stories about people like Einstein who had dyslexia but were still geniuses in one "intelligence." Then I created a "modified" Science program that allowed students to have an individualized work and assessment program. This was done in conjunction with the school "Student Welfare" teacher and with the parents. Involving the family was a big plus. All of this planning was initially much more work; however it reduced misbehavior and increased learning because students were less frustrated as they felt in control of their learning.

Step 3: Help the Students "Know What They Know" by Reflecting upon their Skill Level

The ultimate goal of this sustainable learning paradigm is the toughest: can the students explain to others in written or oral form what they know, and are they able to track and predict their marks? I was lucky enough to attend a four-day workshop entitled *Quality Learning* (Langford, D.). The Ministry of Education in the State of Victoria is working with the Australian Quality Council (www.agc.org.au) to instill, voluntarily, Demming's Quality Management Processes (Walton, M. 1986) into school administration and classroom teaching. To quote David Langford:

> "The results of using Continuous Improvement Processes were dramatic. Using basic statistical tools students were able to chart their own learning process, evaluate their work and start taking responsibility for their learning." (Langford, D.)

The values that go along with this very quantitative and rigorous approach to student learning can, with some thought, be instituted into any class, school or school system, as it focuses on processes, not curriculum. Some fundamental beliefs are:

- Grading is not a motivator.
- Students can and should help plan their own learning processes.
- Failure is a learning experience.

After several months of working with the above methods, in a constant feedback cycle, I was able to see that I was getting close to my goal of students learning for learning's sake. I was spending my time working on learning processes, rather than classroom management and discipline; in other words, to use a Quality Improvement aphorism, I was working on the System, not in the System.

The payoff in terms of spreading these approaches with other teachers was:

- Many came to workshops I offered.
- Several asked for resources so they could teach this way ***because the students asked*** them to.
- The Principal asked me to make a presentation on Layering to the governing School Council so that this method would be officially recommended to all teachers for the following year.

Those who dare to teach must never cease to learn. - Socrates

Case Study #2
Teaching Staff of New Town Primary School, Singapore – *Encouraging Risk*

On the return flight from Australia, I was invited to present a half-day workshop on the use of the Quality Learning values and methods based on Systems Thinking processes. Although the two cultures and educational systems could not be more dissimilar, both had arrived at one key shared point: that learning more "stuff" did not make a better education. In Singapore, the government initiative to spur on more creative thinking is called "Thinking Schools." (Yin Mee) An example of the kind of shift in method and values that Singapore is attempting is given by this comparison below. (Deitz, M. 1996)

Sustainable Interest *continued on page 6*

Current Design		**21st Century School**	
Design Element	**Consequence**	**Design Element**	**Consequence**
1 teacher & 1 class	isolation	teams teaching	adaptability
external control	fragmentation	internal control	commitment
staff are replaceable parts	alienation	variety of staff roles	flexibility
isolated tasks	simplification	integrated task grouping	learning
1 best way	conformity	many "right" ways	innovation

Sustainable Interest in Modeling in the Classroom continued from page 5

The cultural norm of "saving face" and not admitting to mistakes makes innovation and risk taking very difficult in Singapore. What I call step 2 of the sustainable learning curve—RISK—was the challenge presented to me as I presented a five-hour workshop entitled "Systems Thinking & Quality Learning: How Can the Best Get Better?" (Kubanek, G. Singapore 1999) In the workshop, the focus was on using experiences and provocative systems games (Booth) to get the teachers out of their comfort zones. The key learning tool was a simulation called Fishbanks (Meadows). Based on the feedback sheets, new insights that would stick came about when the ***teachers experienced learning*** rather than being told or shown this new way of teaching.

Upon reflection and after reading the feedback from the participants, my guess that experience, rather than information and explanations of theory, made an impact on "hooking them" into teaching like Systems thinkers was validated. However, the degree to which experiential "playful" learning (in the sense of using simulations as Schrage) worked and the degree to which my explanations had virtually no impact, shocked me. It seems that adults, even more than students, need to be in charge of their learning, work in teams, be motivated by curiousity and know that their leadership is there to support them, not "boss" them. I was grateful for the teachers' feedback as it made clear that it is more difficult to get adults than students on board the "Systems thinking bandwagon." Only by personal exploration in a non-threatening experience did the adults open up to a new way of teaching and learning.

If you think you can you can and if you think you can't you're right.
- Henry Ford

Case Study #3
Grade 13 Chemistry class in Ottawa, Canada – *Building a Mood for Reflection*

In this grade 13 Chemistry class I noticed that deep learning was being blocked by an obsession with marks. Fear was blocking many students from reaching their potential. They would not work together even when asked. The challenge was to change the "mood" of the class by a subtle shift in values. By using stories, activities and different assessment tools that could make students first enjoy the class, work in teams and use a system dynamics simulation project, I was able to have the students see learning as process rather than a final goal. The challenge here was step 3 of the sustainable learning curve: reflection. But to get to this goal of metacognition, I had to work building in assessment processes that were intrinsic (learning for its own sake) rather than extrinsic (marks-driven results).

As with all sustainable learning, it was a slow start, and the initial "tilling of the soil" was in the "Affective Domain" (emotions). I read stories—for example, some chapters from Goleman's book *Emotion Intelligence*, or the article about the London cabbies whose posterior hippocampus [part of the brain used in navigation] was larger for cab drivers who spent more time on the job. (Freeman) We even played poker one day! Why? Because many students in this class felt that they could achieve only a certain level because they were not "smart," or did not have good support at home, or some other "reason" that allowed them not to take full responsibility for their learning. By using the Poker game as a metaphor (Lectures are useless!) they could begin to see that it was more important how you played your cards (personal effort and social skills) than the cards dealt to you (family background, gender, etc.). Now clearly this is a gross oversimplification, but by using similar techniques almost every day, the mood of the class was subtly shifted and there was even laughter most days.

Once the values that I was striving towards were clear, an Independent Study was assigned. Three options were given, but most students chose to do a system dynamics simulation. The project had several parts: download the instructions to do an oscillating clock reaction from the web, do the experiment and collect the data, learn Vensim enough to build a simple oscillatory model whose frequency would match that of the experimental data, and, most importantly, log the feelings on the learning process. It was made clear to the students that coming back to me for questions, after doing lots of work, was a necessary part of this project. Students who did come for help at key points and thus used me as a "coach" loved the project. Those who were still "afraid" and unable to grasp the fact that there was no "right" answer did not come for help. They were frustrated and did not do well as they were unable to document what they did and why. The role of metacognition, of being able to communicate the stages of learning they went through, was critical to the success of this project. Here are quotes from two of the students:

"As she walked deeper and deeper into the Australian jungle Dihanna didn't know what she would come across. She had been sent into this wilderness by her professor Dr. Kubanek to investigate…" (Kitcher)

*"After observing the real experiment, I understood that I was expected to make a model of what I just saw and hopefully be able to match my observations to the graph the program would produce. I went home, downloaded the program, looked at it and thought "***Huh?***" After discussing the software with Mr. Kubanek, I was shown a preliminary model and I went home to* **play** *around. But I knew that I gave the desired look that I wanted, a nice oscillation back and forth. "However,*

you want the reaction to die off," he said to me. "Look up damped oscillations in the .pdf manual that you can download from the website. You will need an Adobe reader as well." Pdf manual? Adobe reader? That's when the real fun started." (Orchard)

While the students were working on this project outside of class time, I kept hammering away every day, five minutes only, to get them to value process over result and to see the question as more important than the answer. Examples of methods used to do this were deBono's alternate route game (deBono, E. 1995) and his presentation on using provocation (deBono, E. 1998) to enable movement out of your comfort zone. I also read them chapters from Schrage's book *Serious Play*, (Schrage, M. 1999) and showed them some "microworlds" downloaded from the internet that showed that "big people" also valued exploratory learning where there was no one "right answer."

Altogether, after several months, the learning in the class changed dramatically in style and mood. The students were now comfortable working in teams, going to the board to explain their solutions—making mistakes was OK. They enjoyed the class much more and, finally, there was a marked improvement in the quality of learning. All these Strategic Learning (Simpson & Nist) methods meant that learning was as much about ***"learning how to learn"*** as it was about the content of the chemistry course. With the sustainable learning curve in mind, with the three steps of Passion – Risk – Reflection, learning tools were selected and employed that turned memorization for the test into metacognition of how Science is learned and how Scientists interpret the world.

The results are encouraging. Spreading the value of active, student centered learning within the school has been excellent. Other teachers and student teachers have tried several of the ideas. I now DO what I believe is best for students: teaching using this three-step Systems Thinking template to build sustainable learning. The use of computer simulations as a theme for a grade 10 Ecology project has been enthusiastically welcomed, and the Principal has been a great supporter of more computer, student-centered learning styles. Furthermore, the local Board has sent me to conferences, workshops and invited me to speak at several workshops on the use of the above described teaching strategies.

Learning is not a spectator sport.

Conclusion

The educators at the more senior levels understand very well that all these efforts are instilling a different mood into the class where learning is personalized, and where Senge's ideas of creating learning organizations is beginning to take fruit. As stated in the Abstract, building sustainable learning is about changing the power equation; but with this power comes responsibility. As Senge himself said once in an interview (O'Neill):

"One characteristic of an organization that has a very low ability to learn is that people at all levels see themselves as disempowered; ***they don't think that they have leverage*** *to make any difference."*

Since these experiences, other tools have appeared on my desk that provide routes to enable students to take charge of their learning. These tools all revolve around web based training—using the internet as a learning tool in high schools. I am currently involved in a Pilot project use of one such web based learning package from the EDEN Project. (EDEN, 1999) However take note; ***there is no one solution*** in building a sustainable learning environment that engages and challenges all learners: (Sagor, 1995)

"In schools where teachers are active learners, excitement and curiousity contribute to a rich learning environment."

Even before the Information Age, the following quotation (Chamberlain et al. 1942) highlights the value in the search for tools that support improved student performance and upholds the learning organization paradigm:

"The most successful schools are characterized not by the particular innovation they had adopted but by ***their willingness to search and struggle*** *in pursuit of valid objectives, new strategies, and new forms of assessment."*

In the Information Age, schools are in danger of making themselves irrelevant if they do not shift their focus from teaching to learning, from control to choice, by using ideas like these presented in a whole systems framework. By using Systems Thinking structures, any school in the world, at any age level, with students of any academic ability, can benefit from a shift to active, student-centered learning the "System Dynamics" way. To change the way students learn we must first change our mental model of what teaching is about, and be mindful of what Albert Einstein said:

Our theories determine what we measure.

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This article is available with references at the CLE Web site www.clexchange.org *as SE2000-06SustainablInterest.*

What Behaviors Are Desirable in Students Creating System Models? A Step before Assessment

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Assessment is a major concern currently in the K-12 systems community. If parents and other teachers are to be encouraged to accept this new paradigm for problem solving and analysis, then some method for measuring the improved thinking skills of students must be demonstrated. How to accomplish this assessment using traditional tools has proven to be elusive. This presentation attempts to take one step back from the assessment issue and determine what we feel are desirable traits in a student or student group that has chosen to study problems from a systems perspective. The analysis will be broken into three categories: creating models in a modeling course, transferability to other classrooms/disciplines, and indication of improved understanding of concepts presented in other classrooms/disciplines. In a modeling course, attention will be given to skills involving determining reference behavior, model design, model validation, and model explanation. For transferability, the topics will include a focus on model structure and what lends itself to transferability. For improved understanding, some student behaviors that demonstrate a student has surpassed typical conversations will be suggested.

Desired Behaviors of a Systems Modeling Student

Year 1

Early in the student instruction, most effort is exerted just trying to teach students how to create readable, simple diagrams (with attention to dimensional consistency) and present information in a graph or table that is relevant, readable, and displays key points of interest. There is also emphasis on communication, so helping students learn to write explanations that highlight the important information in complete and fluid paragraphs requires significant time and energy.

1. Uses software well enough to create diagrams, tables, graphs.
2. Can design models to replicate three generic structures: linear, exponential, convergent.
3. Can design a simple model that is easy to read: good design, no crossed lines, appropriate # flows, simple to glean major components, names of icons are meaningful.
4. Can create graphs that tell a good quick visual story: choice of graphs to display, choice of scale, units.
5. Can identify appropriate units for every equation.
6. Can explain design of model, dependencies, choice of stock, flow, converters.

After achieving a certain level of competency in the mechanics of model construction, emphasis shifts to the beginning concepts of systems modeling.

7. Can explain using a graph, how flows determine change of behavior in a stock.
8. Can trace and explain simple +/- feedback.
9. Can transfer simple structures across topics.
10. Can use basic commands: step, pulse, if-then-else, appropriately.
11. Can choose Euler vs. Runge-Kutta appropriately. Can choose DT size appropriately.
12. Can explain what a system is.

The next step is to have students begin to extend their learning/application of SD outside the teacher-made SD lessons.

13. Can select an appropriate topic to model.
14. Can gather, interpret, translate data to use in a model.

***Assessment** continued on page 11*

Figure This! Family-Friendly Math Challenges

Learning high-level mathematics takes more than forty minutes a day in the classroom. Students—especially in middle school grades—need the support of teachers, families and friends to understand the excitement and energy of mathematics both in school and in the world.

The Figure This! initiative provides families with challenging math activities that help middle school students learn higher level mathematics they need to know. The challenges are FREE and available online at www.figurethis.org or call 1-877-GO-SOLVE.

Figure This! needs community and corporate partners to promote and distribute the challenges to employees, members and customers. This can be a valuable way of enhancing any organization's family involvement and local school improvement efforts. For more information, contact Jessica Schwartz at the Widmeyer-Baker Group (jessica.schwartz@twgb.com or 202-667-0901) Figure This! Is supported by the National Science Foundation and the U.S Department of Education.

System Stories for Children

Linda Booth Sweeney, Harvard Graduate School of Education

As the parent of a wonderfully inquisitive toddler, I frequently find myself wondering how he will learn to live in a world where everything everywhere appears to be connected to everything else. Or, as a system dynamicist might ask: how will he learn to understand and predict the behavior of social systems that are increasingly dynamic and complex? What does he need to learn, to understand, for example, the escalating behavior of two bullies on a playground; the impact of oil spills on the environment; the spread of epidemics, or boom-and-bust cycles in the marketplace?

As I consider my own son's learning process, I see that much of what he learns comes from the reading and rereading of favorite books. (On some days, he'll devour 20 books before bedtime.) Common sense and, now, a growing body of research, tell us that children remember what they hear and learn through stories.[1] All this evidence in favor of story as a powerful educational method invokes the question: why not learn to think systemically through story?

But how many children's stories embody systems principles? Over the past several years, I've been on an absorbing journey in an attempt answer to that question. I discovered that many stories embody linear event-and-reaction relationships; the characters' actions never have unexpected changes, and the plot moves forward from beginning to end. One has to wonder, *are we (particularly in Western cultures) actually "set up" by the structure of our stories, habituated at an early age to look for linear cause and effect relationships?*

However, I also found a growing number of stories that embody systems principles and archetypes. I've included two of my favorites here. This excerpt is taken from a longer piece that includes an introduction to targeted systems concepts, an analysis of 15 stories and tips on how to use the collection. I am now in the process of turning this paper, which emerged from a pilot study conducted at the Harvard Graduate School of Education, into a booklet for parents and educators. If you have comments or other stories you would add, please get in touch.

If You Give a Mouse a Cookie
By Laura Joffe Numeroff, illustrated by Felicia Bond, HarperCollins 1985; picture book, fiction, targeted at ages 3-7.

Systems thinking concepts: Simple interconnectedness, circular feedback, unintended consequences, delays, selecting time horizons, solutions often create new problems.

This is the story of the unforeseen consequences of giving a hungry little mouse a cookie. Seems innocent enough? But the next thing you know, the energetic mouse will want a glass of milk. Then he'll want to look in a mirror to make sure he doesn't have a milk moustache. Then he'll ask for a pair of scissors to give himself a trim, and a broom to sweep up. The mouse rascality tumbles on like dominoes throughout this delightful book. At the book's end, we are back to where we started, with the mouse requesting yet another cookie.

In real life, people tend to exclude side effects, feedback processes, and delays when making decisions. We all need practice. This is a good story to help older kids (ages 7-10) practice the skill of tracing cause and effect relationships to see how an event (giving the mouse a cookie) feeds back on itself.

As a way to explore the systems thinking related lessons in the book, first ask your students or child to think about different kinds of cause and effect relationships. For example, there are what can be thought of as domino models (A causes B causes C). Children may just call them "dominos." We see domino models in a simple food chain. Another model of causality is one that is circular (A causes B causes C which impacts A). Reading *The Day Jimmy's Boa Ate the Wash* (by Trinka Hakes Noble) or Felicia Bond's *Tumble Bumble* in conjunction with *If You Give A Mouse A Cookie* provides a way to contrast a cyclical feedback model with a linear, domino model.

For younger readers (age 3-6), you may also simply ask:
• What happens?
• When have you seen this same kind of thing happen, when one thing makes another thing happen and then another until you end up back where you started, and you keep going around?

For older readers, you may ask them to trace and visually depict the circular causality in the story and consider some of the following questions:
• What other types of chain-of-events situations can they think of that eventually feed back on themselves?
• What are the possible unintended consequences of some solutions to everyday problems? (For instance, suppose city planners add an extra traffic lane to a crowded highway. Would this produce less traffic or more traffic?)

Voices from the Field

Tim Lucus, Director of Curriculum and Instruction, Glen Rock Public Schools in New Jersey, and contributing author to the *Schools that Learn Fieldbook*, has used this story with children in kindergarten through the fourth grade:

"We were able to unearth some important systems thinking and system dynamics language that we could build on, and we introduced causal loops. We worked with the ideas of stocks and flows.
"Students started with the idea of the bathtub, but then started to see other objects in the classroom and school as stocks and identified the flows that impacted them. We started with garbage cans, (who filled them and emptied them), lunch boxes, lost and found boxes in the office, and

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even classrooms filled with students. We were able to draw simple STELLA maps (not models) and identify converters that impacted the flow. As an example, the number of students in a class (stock) was impacted by new families that moved in and out of the school community, and the number of houses on sale in the neighborhood.

"We also expanded students' mental models of the use of a word or concept—like 'home.' We would send teams of students throughout the school looking for homes. They would report back that your nose is a home for your glasses, your pocket is a home for your pen, a parking lot is a home for a car, etc.

"One of our culminating activities was to have the students make their own circular story and draw out the major events on a long (4 ft.) strip of paper, similar to a cartoon. Then we would make a circle out of the paper by taping the ends together with the pictures inside. If you stuck your head in the circle or story and spun the cartoon you could never tell where the story started or stopped (e.g., a causal loop).

"We would hang them from the ceiling in the classroom with some careful stringing at 'kid height.' Students would walk around the room, stick their heads in a paper circle, and spin each other's stories. We were definitely 'spinning tales.'"

Partner Stories: Other books by Numeroff which reinforce the notion of circular causality: *If You Give a Moose a Muffin;* Laura Joffe Numeroff, Felicia Bond (*Illustrator); If You Give a Pig a Pancake*; Laura Joffe Numeroff, et al, and *If you give a Bunny a Birthday Cake.*

The Butter Battle Book

By Dr. Seuss, Random House, New York, 1984; picture book, fiction, targeted at 4th grade reading level and up but excellent for adults, too.

Systems thinking concepts: Simple interconnectedness, cyclical models of feedback, positive feedback loops, escalation, "structure drives behavior drives events," how (perceived) rational microbehavior can lead to disastrous macroresults.

In this story, Dr. Seuss tells of a feud between the Yooks and the Zooks. The source of the conflict—one clan eats their toast butter-side-up and the other eats it butter-side-down. They build a wall to keep the two clans apart and begin their feud with hand-held slingshots. Eventually, they move onto more sophisticated weaponry, building Triple-Sling-Jiggers and such, until each side has the capacity to destroy each other, and the world!

As the Yooks and the Zooks roll out a succession of increasingly fantastic and dangerous weapons, Dr. Seuss sets up a compelling paradigm for the cold war arms race. Looked at from a systemic perspective, the on-going feud between the two Seuss-ian tribes provides educators with an opportunity to explore the archetypal dynamic of escalation and possible high-leverage interventions.

Escalation generates some of the most troubling systems behaviors we face, and is one of the more commonly occurring system structures. Young children immediately understand this archetype when the example of two bullies on a playground is given. One shoves the other, the other shoves back harder until an all out brawl ensues. In organizations, the "escalation" archetype can be found in typical price wars. In a more deadly confrontation, the escalation structure can lead to catastrophic consequences. The Cuban Missile Crisis in 1962, for example, caught U.S. President Kennedy and Soviet Chairman Khrushchev in an escalation structure that led their countries to the brink of nuclear war. The arms race between the Soviet Union and the U.S. is another example.

In *The Butter Battle Book*, the conflict arises, as we know by now, over which side to butter one's bread. The reinforcing nature of this conflict can be found in the two intersecting balancing loops illustrated in figure 1 below.

The conflict then grows as follows: one party (The Zooks) takes actions that are perceived by the other as a threat ("a very rude Zook by the name of VanItch snuck up and sling-shotted my Snick-Berry Switch!") The other party (The Yooks) responds in a similar manner by building a "Triple-Sling-Jigger" and increasing the threat to Zooks. As a result of this move, the Zooks take even more threatening actions.

After asking students to draw the causal relationship inherent in this story, ask them to consider the following questions:

• What happened? What do you think might happen next?

• What other stories, either from real life or not, include the same kind of behavior?

• In your opinion, who or what is being threatened here? What is the source of the threat?

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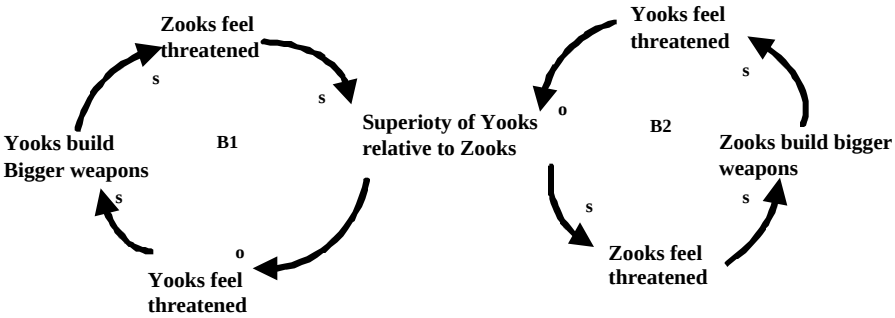

Figure 1: Escalation Structure

Materials Now Available from the CLE

The following previously unlisted documents are available from us or the Web site www.clexchange.org

CROSS CURRICULAR

CC1999-09DevelopngTeamRules **Developing Team Rules.** Jan Mons

From the GIST Project. Students and teachers work together in an inductive lesson leading to a stock/flow diagram of a positive learning environment. [Cross Curricular, Elementary School, Middle School] ($1.00)

SYSTEMS EDUCATION

SE1997-03BucksForBytesModel **Bucks for Bytes: A model to explore strategies and ideas about technology acquisition.** Matt Hiefield

A discussion and model to help identify the crucial points in the process of acquiring computers for classrooms. [Administration, Systems Education, K-Adult] ($1.00)

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15. Can communicate in a businesslike manner on the phone or with e-mail with a consultant or organization to gain more information about modeling topic.
16. Uses a model to test policies.

Year 2

Students build modeling skill and expand their reach outside the SD classroom.

1. Can explain more complicated +/- feedback.
2. Can build models of three generic infrastructures: s-shaped, oscillation, overshoot & collapse.
3. Can identify system scenarios in newspapers and magazines.
4. Can create simple model structures of different system scenarios from newspapers and magazines and explain the structures.
5. Can identify leverage points in a model.
6. Can explain transfer of loop dominance.
7. Can use multipliers appropriately.
8. Understands how delays affect behavior of a system.
9. Can identify system scenarios and generic structures in topics studied in other classes.
10. Can explain an appropriate systems relationship to a teacher/student in another class.
11. Has an appreciation for the breadth of disciplines to which systems applies.
12. Tests model's robustness.
13. Can differentiate between event reporting and systems/feedback approach reporting.

Year ?

At this point it is hoped that modeling has become a comfortable tool the student will use to understand her/his world.

1. Applies system tools/structures to enhance student's own learning.
2. Uses core structures to help understand/describe new systems.
3. Improves ability to explain model behavior.
4. Improves ability to articulate what they learn from the modeling experience.

This article is available at the CLE Web site www.clexchange.org *titled SE2000-06BeforeAssessment.*

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• For kids: What do you think the different characters were thinking (cite different points in the story.) For adults: What are the deep-rooted assumptions that lie beneath the actions taken in response to the threat?
• Is there a larger goal here that might include the individual goals?

Partner Stories: For another story that addresses escalating behavior, see *Billibonk and the Thorn Patch* by Philip Ramsey.

[1] For two related references, see Kieran Egan's book, *Teaching as Story Telling: an alternative approach to teaching*, University of Chicago Press, Chicago, Illinois, 1986. Also, see Usha Goswami, article: *Analogical Reasonig in Children, Essays in Developmental Psychology*, Lawrence Erlbaum Associates, Hillside, 1992.

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Educators' 30% Discount on *The Systems Thinking Playbook, Vols. I & II*

In Dennis Meadows' article *Use of Gaming as a Tool in Education: Resources for Teachers*, in the Winter 2000 issue of *The Exchange*, one of the resources listed was the following:

- Booth Sweeney, Linda and Dennis Meadows, *The Systems Thinking Playbook, Vols. I & II*, published privately, 1996.

This small red binder contains 20 exercises with extensive narrative about how each can be linked to the skills, attitudes, and habits required of a "systems thinker." It is presently priced for the corporate training market, so it costs $69.95.

Ms. Booth Sweeney has asked us to make sure that educators know there is a 30% discount, so we would like to iterate that the above price is for businesses and that *educators receive a 30% discount.* For more information, contact the Game Sales and Promotions Manager at ipssr.games@unh.edu. *The Systems Thinking Playbook*, http://www.unh.edu/ipssr/Lab/playbook.html .

The Systems Thinking Playbook, Vol. III

The third volume of ***The Systems Thinking Playbook*** (co-authored by Linda Booth Sweeney and Dennis Meadows) will be available in several months. If you are interested in receiving a description of this volume and information about ordering, please contact Game Sales and Promotions Manager, Institute for Policy & Social Science Research (IPSSR) UNH/Thompson Hall, Room G01, 105 Main Street, Durham, NH 03824
Telephone: 01-603-862-2244 FAX: 01-603-862-4140
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