



the Creative Learning EXCHANGE

Volume 13, Number 2 - Spring 2004

Tips for Using System Dynamics Tools

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Introduction to System Dynamics Tools

System dynamics uses a set of tools that allows its practitioners to visually and succinctly depict interpretations or mental models of systems, communicate those mental models to others and increase understanding of systems. Often the tools will be used together to logically develop and capture a complex mental model; at other times a single tool will be a powerful means to develop some understanding. There is no single formula for the use of any of these tools, but there are a number of hints or tips that can help bring about clear, powerful insights from their use.

A quick overview of the basic system dynamics tools:

Behavior-Over-Time Graphs (BOTGs):

A BOTG, consisting of a line graph with time on the X-axis, captures one of the most fundamental aspects of system dynamics—the focus on dynamic, or changing, systems. This simple tool can help students focus on patterns of change over time rather than on isolated events, often leading to rich discussions on how, and ultimately why, something is changing.

Causal Loop Diagrams (CLDs):

In addition to depicting the behavior of critical elements of the system, another

challenge involves understanding and communicating the interactions that determine those dynamics. At this point, the focus shifts from describing the “what” of the system’s behavior to the “why” of its behavior. Central to the idea of system dynamics is the belief that system behaviors are generated from within the system and that they are the result of one or more causal, or feedback, loops. To understand the behavior we must identify and understand those feedback relationships. Causal loop diagrams (CLDs) provide one way to visually capture those relationships.

Stock/Flow (S/F) Maps:

Stocks represent the accumulations in a system. Fundamental to the concept of dynamic systems is the idea that the dynamics (changes) of stocks are caused by combinations of in- and out-flows that act in concert to increase or decrease those stocks. Those flows, in turn, are controlled by a variety of feedbacks within the system. The multiple factors that may be influencing the flows and contributing to the feedbacks that control the system’s behavior can be better understood by graphically representing the stocks and flows and their relationships.

Computer Simulation Models:

The most comprehensive way to test your understanding of how a given system “works” and what policies might

change that behavior is to actually build and explore a computer simulation of that system. A computer model can extend understanding by simultaneously computing all of the system’s many interdependent relationships over time that have been built into the model—a task too complex for the human mind. “Tips” for such computer modeling efforts, however, are too extensive for a one-two page summary. To learn more about models and modeling, visit the following websites for information and links to other sources of information:

- www.watersfoundation.org (See Training Information/Self-Help.)
- www.clexchange.org (See Additional Resources/System Dynamics in Education.) To gain further knowledge of all of the tools, consult “Rubrics for Understanding,” available on the Creative Learning Exchange website.

The preceding “Introduction to System Dynamics Tools” was written by staff at the Creative Learning Exchange and edited by staff members in the Catalina Foothills School District (CFSD). The following “Tips” sheets were prepared by staff members in CFSD and were updated in conjunction with the staff at the Creative Learning Exchange.

Tips continued on page 3

Updates...

Editors Note:

If you would like to pursue the concepts raised in the article *Systemic Planning* in the last issue of the *CLEExchange*, a good place to start would be *Classroom Dynamics*, by Ellen B. Mandinach and Hugh F. Cline. They have a stimulating discussion of future research and policy implications, as well as a draft model of computer-based curriculum.

We also discovered that Ellen has been given a major award by the National Science Foundation to develop an evaluation framework using systems thinking as the philosophical and methodological basis for examining the implementation of technology in schools. We will look forward to her continuing excellent work in this field.

EDITORIAL

As the school year draws to a close, the CLE is working hard on two major events, *DynamiQUEST* and the Systems Thinking and Dynamic Modeling Conference.

DynamiQUEST is a particularly exciting day with kids in grades 3 through 12. We try to create a day where the students meet and talk with people who are knowledgeable about system dynamics. The students discuss their projects with the coaches and teachers to gain insight and challenges for the next step in their learning. Anyone who is in the Boston area on May 14 should try to stop by. It is a *really* fun day! If you can plan to come, just give us a call at the CLE to tell us.

The other big event is our biennial Systems Thinking and Dynamic Modeling Conference, to be held this year at Skamania Lodge, in tevenson, WA. The draft list of presentations is available in this issue of the *CLEExchange*. The conference promises to be a challenging and informative learning opportunity. Call or e-mail Andi Miller milleras@clexchange.org or go to our website www.clexchange.org if you would like more information.

Enjoy the spring with the wonderful green grass, the daffodils and tulips!

Take care,
Lees Stuntz (stuntzln@clexchange.org)

New Book Coming This Summer!!

The Shape of Change

By Rob Quaden and Alan Ticotsky
with editorial help of Debra Lyneis

How can we introduce teachers and their students to the basic concepts of system dynamics and systems thinking?

This book presents eleven engaging classroom activities, from games to connection circles, complete with easy directions, thoughtful explanations, student worksheets, and no technical language.

The book will be available for purchase at the ST/DM Conference at a special price.

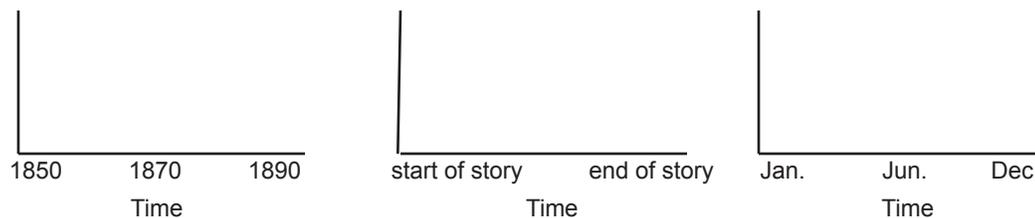
Tips for Using System Dynamics Tools continued from page 1

Tips for Behavior-Over-Time Graphs (BOTGs)

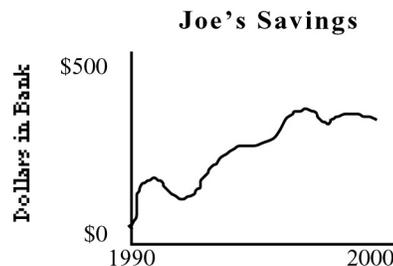
Behavior-Over-Time Graphs (BOTGs): A BOTG is a simple tool that can help people focus on patterns of change over time rather than on isolated events, leading to rich discussions on how and why something is changing.

1. A BOTG is a basic line graph showing the trend, or pattern of change, of a variable over time.
2. The X axis:
 - is **always** labeled in units of time or can reflect change in time.
 - has defined beginning and ending points; the precision of the definition can meet your specific purpose.

Care should be taken to explain the logic for the time scale. Why does it start and end where it does? Examination of when and where a particular pattern of behavior starts, ends, or changes direction is also important.



3. The Y axis:
 - clearly identifies the variable being graphed and **must** be labeled with that variable's name.
 - should not include qualitative words such as more, less, increasing, bigger, etc., in the variable's name; for example, it's difficult to understand "more fear" decreasing over time.
 - may represent "concrete" variables (quantities such as population or temperature) or "abstract" variables (like love or stress).
 - must have a defined scale. Scales can be numeric (e.g., 2 to 1000 rabbits or "on a scale of 0 to 100...") or descriptive (e.g., low vs. high).



4. Different interpretations of the behavior of the variable are definitely possible. Both similarities and differences among graphs are grounds for rich discussion about individual interpretations or mental models.
5. More than one variable can be plotted on the same graph to compare them for possible interdependence or causal relationships between variables. Differentiate between the lines with careful labeling or the inclusion of a key. This step can contribute to thought-provoking discussions.

Tips for Using System Dynamics Tools continued from page 3

Tips for Causal Loop Diagrams (CLDs)

Causal Loop Diagrams (CLDs) help one understand and communicate the interactions that determine the dynamics of a system. System behaviors are generated from within the system and are the result of one or more causal (or feedback) loops.

1. CLDs show causal relationships and illustrate circular feedback within a system.

A cause becomes an effect, becomes a cause. You should be able to read around the loop several times. "What goes around comes around."

2. You may choose to identify important CLDs by looking for causal relationships among behavior-over-time graphs (BOTGs) that describe the system or by extracting those found within Stock/Flow maps and computer simulations.

Since CLDs are about the causes of change, it is helpful to identify how key elements actually did change by drawing accompanying BOTGs (See Fig. 1: As drug use goes up, dependency goes up; as dependency goes up, drug use goes up.)

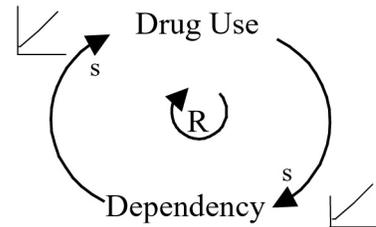


Figure 1

3. Find a specific focus for the loop(s) you draw, taking into account the purpose and audience for the loop(s). A CLD can help you tell a story or express your interpretation or mental model of how a system works. A single, understandable CLD can describe a simple system or a part of a more complex one.

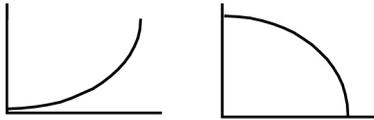
Pick one aspect of the system. Focus on a behavior that is changing over time. What are the causes? What are the effects? This/these become the other aspects of the loop(s).
4. CLDs contain 4 elements (See Fig. 1):
 - a. variables that are related in cause/effect sequence(s) (See #5 below.)
 - b. arrows that indicate which elements are affecting other elements
 - c. symbols associated with the arrows that denote the direction of the influence of the relationships (See #6 below.)
 - d. a central symbol indicating the overall identity of the loop (either "R" reinforcing or "B" balancing) (See #7 below.)
5. All variables in a CLD must be able to increase or decrease; at least one must be a stock, i.e. an accumulation. (See "Tips for Stock/Flow Maps.")
 - a. Choose precise, non-repetitive terms for the variables in CLDs, e.g., "Feelings" is too nebulous a term to include in a loop. Try a more specific feeling such as "happiness," "sadness," or "frustration" instead.
 - b. Do not use words such as more/less, or increases/decreases in the variable name. It is very hard to interpret less "more drug use" or more "less drug use."
6. Symbols associated with the arrowhead end of each arrow indicate the effect of the influence.
 - a. An "S" means that both variables move in the same direction. If the first variable increases, the second variable will be greater than it would have been otherwise; a decrease in the first causes the second to be less than it would have otherwise been. A "+" may be used in a similar although not identical fashion.*
 - b. An "O" shows that the two variables change in the opposite direction. If the first variable increases, the second will be less than it would have been otherwise; a decrease in the first variable causes the second to be greater than it would have been otherwise. A "-" may be used in a similar, although not identical, fashion.

*For clarification of the difference between "S" and "+" and "O" and "-", refer to writings by John Sterman and/or George Richardson.

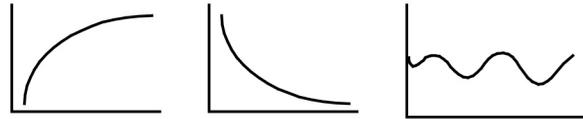
7. A CLD may be “reinforcing” and grow, or shrink, until acted upon by a limiting force, or “balancing” and move toward, return to, or oscillate around a particular condition. Reinforcing loops are marked with an “R” in the center; balancing loops are indicated with a “B” in the center.

Graphs of behaviors from:

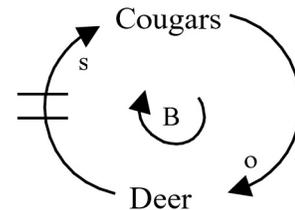
Reinforcing Loops



Balancing Loops



8. If there is a significant amount of time between the action of one variable and the reaction of the next variable in the loop, a time delay can be indicated by drawing two short, parallel line segments across the arrow that connects those two variables.



Tips for Stock/Flow Maps

Stock/Flow (S/F) Maps: Stock/Flow (S/F) maps can show interdependencies and feedback within a system by identifying major accumulations and the factors that increase and decrease them over time.

1. Definitions:

stock: an accumulation of “stuff,” either concrete (e.g., dollars) or abstract (e.g., anger), that can increase or decrease over time. Stocks are the “nouns” in the system and should be named (and labeled) as such. Stocks can only be modified through flows.

flow: action or process that transports “stuff,” directly adding to (inflow) or taking away from (outflow) the accumulation in the stock. A flow is always a rate and is defined in terms of units of the stock per unit of time (“stuff” in the stock per time). Flows are the “verbs” in the system and it’s best that they be labeled to reflect that—e.g., “dollars added/ing (per month)” or “anger released/ing (per hour).” The “cloud” at the end of the flow symbol represents the boundary of the system.

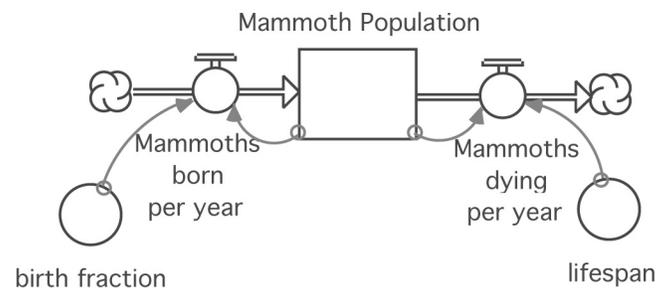
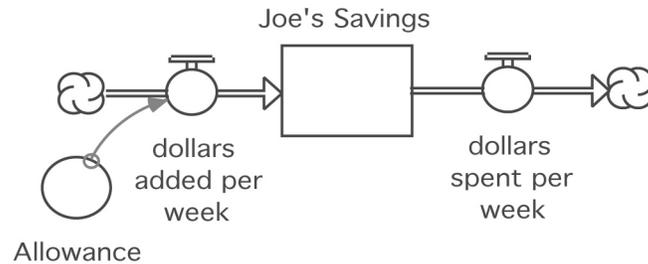
converter: holds information about the system that affects the rate of the flows, or that affects the value of another converter, e.g., allowance affects the rate of dollars added per month.

connector: moves information from one element of the system/map to another. You can think of a connector as a “wire” that carries information (in contrast to a flow that carries “stuff”). It originates at the point where it “picks up” that information and terminates (the arrowhead end) at the place the information is delivered. (Remember, stocks can only be affected through flows, therefore you should not attach a connector directly to a stock.)

2. A “bathtub” analogy may help to explain the concept of stocks and flows.
- A stock is like the water in a bathtub, the level of which can change over time.
 - An inflow represents water being added through a faucet; an outflow represents water flowing out through a drain.
 - Converters and connectors determine how quickly the water flows in and/or out.
3. Stock/flow mapping (and computer modeling, for that matter) proceeds by identifying the critical stock(s), then determining what flows are important in changing the amount of the stock, and finally by defining what elements in the system influence the rate of the flow(s).

Tips for Using System Dynamics Tools continued from page 5

4. To identify which **stock(s)** to include in a map, first identify the critical behaviors of the system and create and discuss BOTGs that reflect those behaviors.
 - When choosing a name for any element in a Stock/Flow Map, keep comparative words such as more or less out of the name, e.g., Level of Stress is preferable to More Stress. (See #5 in Tips for CLDs.)
 - Labeling parts of the map clearly is critically important. The labels make the story clear to others.



5. Converters contain information that, ultimately, affects the flows that affect the stocks. Work outward from the flows in identifying those converters. What converter(s) will affect each flow? What converter(s) will affect those original converters?
6. Once you have drawn your stock(s), flows, converters, and connectors, make sure you look for the **feedback** from the stock(s) that makes a system dynamic. Ask questions such as: Does the accumulation in the stock affect its inflow? outflow? converters? other stocks' inflow/outflow/converters?

This article, "Tips for Using System Dynamics Tools," is available in its entirety from the CLE website, clexchange.org, catalogued under Implementation.

DynamiQUEST 2004

May 14th, 9am—3pm

Campus Center, Worcester Polytechnic Institute, Worcester, MA

The what and why...

Students (and teachers) are at various places along the road to developing proficiency with thinking systemically and employing System Dynamics/Systems Thinking (SD/ST) to address complex issues and increase understanding. We seek to encourage students and teachers to develop an understanding of the use of SD/ST tools. We also know that we need an environment, free from the “winner/loser” constraint, where kids can receive feedback from other kids as well as from teachers and professionals well versed in SD/ST. DynamiQUEST creates a venue for both celebrating what has been done and providing encouragement for all to continue!

In this spirit, DynamiQUEST was launched in 2000. DynamiQUEST 2004 will provide a venue for students in Grades 3-12 to showcase work in which they have employed the tools and

method of system dynamics. This effort has several purposes:

- Provide a way for students to meet other students and see what they are doing
- Permit teachers from different schools to see evidence of student work in ST/SD
- Provide a venue for teachers and kids to network
- Have some fun and celebrate with your kids!

The how...

Simple! Have a place where students from around the country can bring their SD/ST work for others to see. Don't pit kids against each other, but hold their work accountable to a set of clearly defined standards (see DynamiQUEST 2004 Rubrics). Give them (and their teachers) a chance to see “where they are” and “where they can go from here.”

But, but...

“My kids are at different stages in learning and understanding the tools and

method of SD/ST. Why would we make the trip just to bring our BOTG's?”

Precisely! The use of standards allows kids to see their work as a point in time along a learning continuum and see where they can go next. DynamiQUEST 2004 provides rubrics for any combination of SD/ST tools from a simple (but powerful) BOTG to a full-blown, dynamic model. The 5th grader's BOTG is as valid as the 11th grader's functional model! Both represent vital stages in the development of a systems thinker/dynamic modeler. Let's take some time to see this work, have kids see each other's work, and celebrate where we are and where we are going.

What now...

Look over the guidelines provided on the website. Begin planning, with your kids, what you will be bringing to DynamiQUEST 2004!

Calendar and Tentative Schedule:

NOW	Students and teachers develop or modify SD/ST applications from their classrooms for inclusion in DynamiQUEST 2004
May 5	Applications due via e-mail (stuntzln@clexchange.org) or mail to: Creative Learning Exchange, 1 Keefe Rd., Acton, MA 01720
May 5	Written proposals due by e-mail or mail to the CLE
May 14	DynamiQUEST 2004
9:00 am	Welcome and group introductions
9:30- 9:50	Poster set-up
10:00-11:00	Group A presents to Coaches, Group B does systems games
11:00-11:20	Snacks and both groups enjoy others' posters
11:20-12:20	Group B presents to Coaches, Group A does systems games
12:30-1:15	Lunch (provided)
1:15-2:30	Problem-solving with Coaches and facilitated by an experienced system dynamics professional
2:30-3:00	Celebration of learning

Draft Program of Presentations for Communication Using Systems Thinking and Dynamic Modeling in K-12 Education

June 30 - July 2, 2004

Skamania Lodge, in the Columbia River Gorge, Stevenson, WA

Keynote Speakers:

George Richardson and John Sterman

The Systems Thinking and Dynamic Modeling Conference will provide resources and opportunity for educators and interested citizens to explore what is current and possible in K-12 systems education. The Conference is designed to involve experienced individuals as well as novices in K-12 systems education.

- Teachers
- Administrators
- Curriculum coordinators
- Citizen advocates
- Business partners for schools

Presenters include:

- Teachers and administrators actively involved in systems education across the country and internationally
- Internationally known speakers and professors in the field of systems thinking and system dynamics

Our presenters and attendees will address multiple interests. Following is a draft list of presentations at the 2004 conference:

1. Introduction to Non-Computer Systems Thinking Tools
2. Introduction to Computer Modeling with STELLA
3. Current Theories and Research Trends in Education: How do they fit with Systems Thinking and Dynamic Modeling?
4. It's Elementary! How elementary school teachers use systems thinking in classrooms
5. Making Meaning at the Middle Level: How middle school teachers and administrators use systems thinking
6. What's Happening in High School? How high school teachers use systems thinking concepts and tools in their classrooms
7. Recruiting and Retaining a High Quality Mathematics and Science Teaching Workforce Using a System Dynamics Simulation
8. Educational Reform at the Edge of Chaos
9. How Drugs Work in the Human Body
10. Creating Content Specific Lessons Incorporating System Dynamics Models
11. Working with the Five Disciplines: the Dutch Way
12. Students and Teachers Work with Systems in a Middle School Setting.
13. Using Systems to Develop Literacy Among Elementary Students
14. Nota Bene – how you will create an useful notebook and learn interesting things about system dynamics
15. Savagery, Fear, and Leadership: Feedback in Lord of the Flies
16. How did I get that grade? - Helping Students See the Effects of Their Academic Decisions over Time
17. Learning Environments in Biology. STELLA-based Food Chain and Fly a Cell
18. Teaching Systems Thinking with Spreadsheets
19. Panarchy: A Metaphor for Conveying Systems Concepts and Improving Systems Thinking Skills
20. What Works in Staff Meetings: A Middle School Principal's Experience Using System Dynamics
21. Manage Middle Eastern Oil with STELLA: the OPEC Simulation
22. How Does a Model Facilitate Learning? Some Preliminary Experimental Findings
23. Environmental Science Models 24. Qualitative Learning of System Concepts through Hands-on Modeling and Simulation.
25. Using Storytelling Features of STELLA to Communicate
26. Using Infection and Population Models in Interdisciplinary Lessons
27. Using Non-Computer Activities in Grades 3-8
28. Systemic Planning and Decision Making
29. Simulating Habitat Restoration: Surprising Results from a Student Project on the Tucannon Salmon Model
30. So What Would a Systems Thinker Do?
31. Using A "Ladder of Engagement" as a Template for Guiding Student Activities with Systems Thinking and Dynamic Modeling

Additional Conference Information

Skamania Lodge is a full service resort located on 175 wooded acres in the heart of the magnificent Columbia River Gorge National Scenic Area, only 45 minutes from Portland International Airport and 2-1/2 hours from the Oregon seacoast. The conference center and hotel provide flexible meeting space, comfortable guest rooms with extra amenities and spectacular views, award-winning Pacific Northwest cuisine, and a lounge open until late in the evening. Golf, tennis, walking trails, pool and fitness center are available on site.

Conference continued on next page

Additional Conference Information continued from previous page

Conference Registration Fee

The conference will run from registration Wednesday morning, June 30, to Noon, Friday, July 2. For further information, call or e-mail Andi Miller at the Creative Learning Exchange. 978-287-0070 milleras@clexchange.org

The conference registration fee, per person, Wednesday AM – Friday Noon, is \$435.00. (Late Fee: add \$50.00 to this rate after May 15.) The registration fee includes the conference, five (5) meals—lunch and dinner on Wednesday, breakfast and lunch on Thursday, and breakfast on Friday—and a continuous break buffet. Registrants must make their own lodging arrangements.

There are three ways to register for the conference:

1. Register on-line at www.clexchange.org with credit card payment.

2. Fax your completed registration form with credit card information to 978-287-0080.

3. Mail the completed form, with payment, to us.

Registrants must make their own lodging arrangements. To reserve a room at Skamania, please call Skamania Lodge at 800-376-9116. The room rate is \$139.00 per night. There are some rooms held for early arrivals Tuesday night, June 29. Deadline for reservations at Skamania is May 15, 2004. The hotel rooms may be sold out well before this date, so register as early as possible to guarantee a room at Skamania.

Other lodging options:

Best Western, 3 miles away. For the special conference rate (\$79.00 + tax, mountain view; \$89.00 + tax, river view, phone 800-595-7108 and mention the ST&DM conference.

Econo Lodge, 1 mile away. For the special conference rate (\$53.00 + tax/

single; \$63.00 + tax/double), phone 509-427-5628 and mention the ST&DM conference.

To be assured of a place, especially at Skamania, please register early. Hotels in the area also fill at this time of year, so make all reservations as soon as possible.

Transportation Information

Blue Star Shuttle. 800-247-2272. \$40.00 per person, one-way, Portland International Airport to Skamania Lodge. Call one week ahead to schedule round trip transportation; give conference name to get this discounted price.

White Van Shuttle. 877-774-9750 or whitevan shuttle.com. \$65.00 1st person, \$5.00 each additional person, one-way, Portland International Airport to Skamania Lodge. Call ahead.

High Performance Systems, Inc. Becomes isee systems

For Immediate Release, March 4, 2004, Lebanon, NH: High Performance Systems, Inc. (HPS) of Lebanon, New Hampshire, announces a name change to isee systems.

“Our new name and logo better reflect the visual nature of our products. We help people to see the systems in their life, in their work, and in their studies. Our software enables you to see interconnections,” says President Jessica Richmond.

Barry Richmond, while an Engineering Professor at Dartmouth College, founded HPS in 1984. His mission was to make the world a better place by increasing people’s capacity for thinking, learning, communicating, and acting systematically. Since its inception, HPS has become the world leader and innovator in systems thinking-based software products and training.

“Our software gives people a powerful tool to generate insights, such as unintended consequences of an action or policy, and then to be able to try out different scenarios on a

simulated practice field. Making mistakes on ‘practice fields’ is a lot less painful, costly, and embarrassing than making them in real life,” Ms. Richmond explains.

Today, isee systems is a thriving, privately held company with substantial global reach in the spheres of business, education, and government. isee systems will continue to pursue its mission by focusing on creating new versions of the software for its core customer base of business consultants and managers (ithink® software users), and university professors, high school teachers, students, and researchers (STELLA® software users). isee systems will also remain focused on providing systems thinking training workshops throughout the year.

isee systems will continue to operate from its headquarters in Lebanon, NH.

For more information, visit www.iseesystems.com or call 603-643-9636.

Newsletter Subscription Information

The Creative Learning Exchange newsletter is available in three different formats:

- On the web site at www.clexchange.org
- As an attachment to an E-mail
- In paper format via US mail (\$15.00 outside the USA)

Since we vastly prefer electronic distribution to paper because it is so much less expensive, please E-mail us at any time when you would like to have an electronic subscription.

milleras@clexchange.org

THE K-12SD LISTSERVE

The K-12SD listserv is a wonderful way to make connections and find resources within the K-12 community. Share your experiences and ask for help. If you are not yet a member, please join us.

To subscribe to the K-12SD listserv, send an email 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" if you are Lees Stuntz. Remember that the quotation marks are not to be included in your message, just the words.

The list is not an overwhelmingly active one, so it will not burden your in-basket, unless there is a lively discussion going on. Our most recent one centered on the conceptual difference in a stock and a flow and why these are important concepts for students to understand. Bring your ideas and questions! Where else can you get answers from both experienced teachers and world-class system dynamics experts?

INTERESTED IN INVESTING?

If you would like to invest in our effort here at *The Creative Learning Exchange*, your contribution would be appreciated. You may donate any amount you wish; perhaps \$50.00 is a reasonable amount for a year. All contributions are tax-deductible.

Enclosed is _____ to *The Creative Learning Exchange* to help invest in the future of K-12 systems education.

Name _____

Address _____

e-mail _____

Thank you!

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The Creative Learning Exchange is a trust devoted to encouraging exchanges to help people to learn through discovery. It is a non-profit educational institution and all contributions to it are tax deductible.