Introduction to Dynamic Modeling

Facilitated by:
Anne LaVigne, Systems Thinking in Schools, Waters Foundation
George Richardson, University at Albany, SUNY

Session Description:
This session is intended for individuals who have some systems thinking background and would like to explore the basics of dynamic modeling software as a way to represent a system. Participants will become familiar with basic icons of STELLA® software (stocks, flows, converters, connectors, and graphs) in order to build simple models that demonstrate linear and compounding growth. They will expand the compounding growth model into a population/resource model and then compare linear and non-linear models. If time allows, participants can also explore simulations of other generic models that are freely available online. Please bring a laptop computer for this session. Email CLE if this is impossible, and they will try to supply one.

Introductions

1. Name
2. School/Job Assignment
3. What is your current concept of how computer modeling might enhance instruction?
Some quotes to consider when creating models:

Having to know the answers puts us in terrible positions from which to learn.  

D. Kim

Some quotes to consider when creating models:

The best explanation is as simple as possible, but no simpler.  

Einstein
All models are wrong, but some are useful.  G. Box

How models might be “useful” to enhance learning

STELLA software allows for the exploration of interdependent relationships that unfold over time. The software may be used within many different curricular contexts (e.g. math, science, social studies, literature), either to have students create models of systems being studied or to utilize pre-made simulations.

A few examples are…
### Social Studies - STANDARD 3: Geography
Students analyze locations, regions, and spatial **connections**, recognizing the natural and cultural **processes** that impact the **way in which people and societies live and interact with each other and their environment**.

### Math - Strand 3: Patterns, Algebra, and Functions
Patterns occur everywhere in nature. Algebraic methods are used to explore, **model and describe patterns, relationships, and functions involving numbers**...  
**Concept 2**: Functions & Relationships  **Describe and model functions and their relationships**. For example, distribution and communication networks, laws of physics, **population models**, and statistical results can all be represented in the symbolic language of algebra.

### Science  
**Inquiry Process** establishes the basis for students’ learning in science. Students use scientific processes: questioning, planning and conducting investigations, using **appropriate tools** and techniques to gather data, **thinking critically and logically about relationships between evidence and explanations, and communicating results**.  
**Concept 3**: Evaluate experimental design, analyze data to explain results and to propose further investigations. **Design models**.

### Language Arts  
**Identify, analyze, and apply knowledge of the structures and elements** of literature.

### Workplace Skills - STANDARD 6
**Students illustrate how social, organizational and technological systems function**.

### NSDC's Standards for Staff Development
Staff development that improves the learning of all students:  
Organizes adults into **learning communities** whose goals are aligned with those of the school and district. (Learning Communities)  
Requires skillful school and district leaders who guide continuous instructional improvement. (Leadership)  
Requires **resources** to support adult learning and collaboration. (Resources)
Habits of a Systems Thinker

- Observes how elements within systems change over time, generating patterns and trends
- Seeks to understand the big picture
- Changes perspectives to increase understanding
- Identifies the circular nature of complex cause and effect relationships
- Changes how mental models affect current reality and the future
- Uses understanding of system structure to identify possible leverage actions
- Checks results and changes actions if needed: “successive approximation”

Surfaces and tests assumptions

- Considers both short and long-term consequences of actions
- Considers how mental models affect current reality and the future
- Seeks to understand the big picture
- Changes perspectives to increase understanding
- Identifies the circular nature of complex cause and effect relationships
- Uses understanding of system structure to identify possible leverage actions
- Checks results and changes actions if needed: “successive approximation”

Introduction to Dynamic Modeling – Session Plan

- Create a simple model of accumulation
- Add structures to create feedback
- Add structures to create shifting loop dominance
- Challenge the boundaries of the Population/Resource model
- See a simple ‘real-world’ model with surprising behavior
- Consider connections to K-12 classroom instruction
- Explore a selection of models (if time allows)
Systems Thinking Process with Concepts to Consider

- Identify Systemic Issues
- "Map" Systems and Processes
- Generate & Test Understanding
- Communicate & Implement Solutions/Insights

- Temporal and Spatial Boundaries
- Change Over Time
- Accumulations and their Rates of Change
- Interdependencies (reinforcing and balancing feedback, loop dominance, thresholds)
- Delays
- Short/Long-Term and Unintended Consequences
- Tradeoffs
- Leverage

Population

- Individuals born per year
- Individuals dying per year
- Actual lifespan in years
- Maximum lifespan in years

Resources

- Resources per individual
- Effect on lifespan
- Resources needed per individual
- Regeneration fraction
- Maximum resources per year

Individuals

- Birth fraction per year
- Desired use of resources
- Resources needed per individual
- Quickest use of resources
- Res used per year
- Res regenerated per year

Effect

- Resources used per year
- Actual lifespan
- Effect on lifespan

Session by Anne Lavigne and George Richardson
Online Modeling Courses

- **iseesystems, inc.** – STELLA® and iThink® Software
  See course information.

In-Person Modeling Courses

- **iseesystems, inc.** – STELLA® and iThink® Software
  See course information.

  - PowerSim–Studio 8 software
    See course information.

  - Ventana Systems – Vensim Software
    See course information.
Systems Thinking Process
with Concepts to Consider

Identify Systemic Issues

“Map” Systems and Processes

Generate & Test Understanding

Communicate & Implement Solutions/Insights

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2009 Systems Thinking in Schools, Waters Foundation
Adapted from isee systems and Pontifex Consulting
Populations and Resources

Overview: This task will focus on building a simple population model and then adding in a stock showing the resources on which the population depends. You could think of these resources in many different ways. Resources could be food the population needs to survive, habitat (e.g. trees), or energy (e.g. oil reserves). To simplify the model, all these specific needs are grouped into one stock, called Resources. Build the model and respond to the questions in the journal space along the way.

Part I: The Basic Population Model
- Build the model as shown below.
- Input the numerical data and equations.
  - Multiply the population and the birth fraction.
  - Notice that this model includes the idea of a lifespan rather than a death fraction. Lifespan is simply how long an individual in the population will live on average. Notice also that you divide the population by the lifespan.

- Create a graph for the population. Notice on the graph that the simulation will run for 200 years.
- Set the scale for the population to be from 0 to 2500.

Journal Entry 1: Describe the basic structure (stocks, flows, converters, connectors) of the population model.
• Run the simulation using the initial values shown. What happens on the graph?

It should look like:  

**Journal Entry 2:** Why is the line flat?

• What do you think would happen if the lifespan were 80 years? 30 years? Run some experiments and then respond to the next journal entry.

**Journal Entry 3:** What happens on the graph if the births are greater than the deaths? If the deaths are greater than the births? Why does this happen?

**Part II: Adding Resources**

You're now ready to build Resources into your model. The amount (stock) of resources will directly affect the population.

• **Journal Entry 4:** How do you think the population will be affected if it needs certain resources to survive?

• Expand your model as shown below.
  • Notice that you will need to rename “Lifespan in years” to “Actual Lifespan in years.”
  • Input all the numerical data and equations except for “Effect on Lifespan,” which is described below.
The model now shows that the amount of resources in a stock will affect how long individuals live. Each individual needs 1 resource. If the “resources per individual” goes below 1, then the lifespan will also go down. To show this in STELLA, we need something called a graphical relationship. It will show what happens to lifespan when the resources per individual goes up or down. Follow the directions to make this special kind of graph.

First open the “Effect on Lifespan” and input the equation shown in the picture below:

Now click on “Become Graphical Function.” Notice that you need to work with four things:
1. The scale of resources per individual/resources needed per individual should be from 0 - 1. (This gives us a fraction of how many resources we have, compared to how many resources we need.)
2. The scale of how lifespan will be affected should also be 0 - 1. (This shows how much the lifespan will be affected by resources. The closer the number is to 1, the less the lifespan will be affected. Remember that math rule about anything multiplied by 1 is itself.)
3. Drawing the graph. Just hold down your mouse button while pointing to the graph to create a line that is similar to the one you see below.
4. Make sure that your graph begins at 0,0 and ends and 1,1. Look at the arrows to check if you did this correctly.
Journal Entry 5: Describe the modifications to the structure (stocks, flows, converters, connectors) of the population model.

- Run the simulation using the values shown. What happens to population on the graph?

It should look like:

Journal Entry 6: Why is the line still flat?
(type response)

- Explore the model using some “What if?” questions. For example:
  - What if each individual needs 2 resources per individual? 4 resources per individual?
  - What if the maximum lifespan is 80 years?
  - What if you start with 400 resources?
  - What if...?

- Journal Entry 7: Explain what you observed and learned from your “What if?” experiments. Be sure to talk about what’s happening on the graph for different runs and why.

Part III: Modifying Resources
You may have noticed that the stock of resources cannot go up or down because there are no flows. Expand your model as shown below. Note that you’ll need to create a duplicate of “Resources needed per individual” with the ghost tool.
At this point, you should notice that there’s still one question mark (?) left inside of “Res used per year.” There’s a special equation that needs to be put into that outflow. Notice that there’s an arrow that goes from the stock of resources to “Max res per year” and then to the outflow. Why are those connections needed?

The reason is that if the resources run out, they can no longer be used. The model needs to check which is smaller – the resources individuals desire versus the amount of resources available. Follow the directions to create a (MIN) function so the computer can determine the minimum (the smaller) amount.

First open the outflow, “Res used per year.” Now scroll down on the Built-in box till you get to MIN. Click on MIN and then create the equation as shown in the picture below.

![MIN function example]

- **Journal Entry 8:** Describe the modifications to the structure (stocks, flows, converters, connectors) of the population model.

- Run the simulation using the values shown. What happens to population on the graph? It should look like: 

- **Journal Entry 9:** Why is the line STILL flat? (type response)

- Explore the model using some “What if?” questions. For example:
  - What if the maximum lifespan is 80 years?
  - What if you start with 4000 resources?
  - What if the resources generate at only .001 per year
  - What if…?

- **Journal Entry 10:** Explain what you observed and learned from your “What if?” experiments. Consider possible curricular connections.
Challenging the boundaries of the model:

What if you set the “Regeneration fraction” of the resources to 1 per year? Run the model and observe what happens to the stock of resources over time. Chances are that it grew out of control! This is, of course, unrealistic in the real world. The ability of the resource to grow would be limited by some element, such as a space limitation. To make the behavior more realistic, you can change the structure of how the resources regenerate by having the regeneration based on the accumulation.

Change the outflow to Resources as shown. Set Max resources to 50000 and create a graphical function for the Regeneration time as shown below.

The equation for the flow is: \((\text{Max}\_\text{resources} - \text{Resources})/\text{Regeneration}\_\text{time}\)

Run the model and try some different scenarios to determine whether or not the resources still grow indefinitely? If not, why? How is the new structure impacting the pattern that you see?

Consider how this model might be useful:

- to learn basic stock/flow structures.
- to learn the basics of modeling.
- to explore how accumulations impact one another.
- to study how populations impact resources and vice-versa.
- to explore reinforcing and balancing feedback.
Building Block Models

Simplest stock and flow structure (no feedback):

Examples:

Simplest balancing loop with an explicit goal:

(Can also have outflows with no feedback; invent examples)
Examples:

Amount of milk wanted in glass

Gap to fill

Pouring

Milk in glass

Pouring adjustment time

Goal for understanding

Gap in understanding

Studying

Current understanding

Time to improve understanding

Current information

Perception gap

Belief

changing perception

Time to adjust perception

Created by George Richardson for “Introduction to Dynamic Modeling” at the 2010 CLE Systems Thinking and Dynamic Modeling Conference
Simplest balancing loop with an implicit goal (zero):

Examples:

Putting two together:

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Simplest reinforcing Loop

Examples:

Simplest nonlinear system:

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Examples:

Population1

Net population growth

Net growth fraction

Population density

Carrying capacity

Cumulative oil production

Oil production

Fractional growth in petroleum production

Maximum recoverable petroleum

Fraction of maximum recovered

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<th>Possible Contexts</th>
<th>Lesson Available</th>
<th>Source of Simulation</th>
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<td>Generic Models, Math</td>
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<td>William A. Prothero, Ph.D.</td>
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Information on Systems Thinking

Waters Foundation Contacts:
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Waters Foundation WebEd: www.watersfoundation.org/webed
Systems Thinking in Schools Wiki – www.stinschools.wikispaces.com

Additional Contacts:
isee systems, inc., 46 Centerra Parkway Suite 200, Lebanon, NH 03766 USA, (603) 643-9636, www.iseesystems.com. iseeyystems.inic can provide you with information on the STELLA® software and workshops.
Note online modules on archetypes at:
http://www.iseesystems.com/Online_Training/course/module6/6-01-0-0-about.htm

Creative Learning Exchange, www.clexchange.org
The Creative Learning Exchange was set up to facilitate communication among teachers and schools nationwide to help create a network of schools using systems education. The Creative Learning Exchange publishes a free newsletter that offers articles on system dynamics in education and sponsors a national conference every other summer.

Resources:
http://www.amazon.com/Systems-One-Introduction-Thinking/dp/0996280519
http://www.chelseagreen.com/bookstore/item/thinking_in_systems:paperback
http://www.amazon.com/Fifth-Discipline-Fieldbook-Peter-Senge/dp/0385472560
http://www.amazon.com/Systems-Thinking-Playbook-Exercises-Capabilities/dp/1603582584/ref=sr_1_1?ie=UTF8&s=books&qid=1277329246&sr=8-1

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# Generic Model/Simulation

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<th>Generic Structure/PATTERN</th>
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## Lesson/Assessment Outline