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?

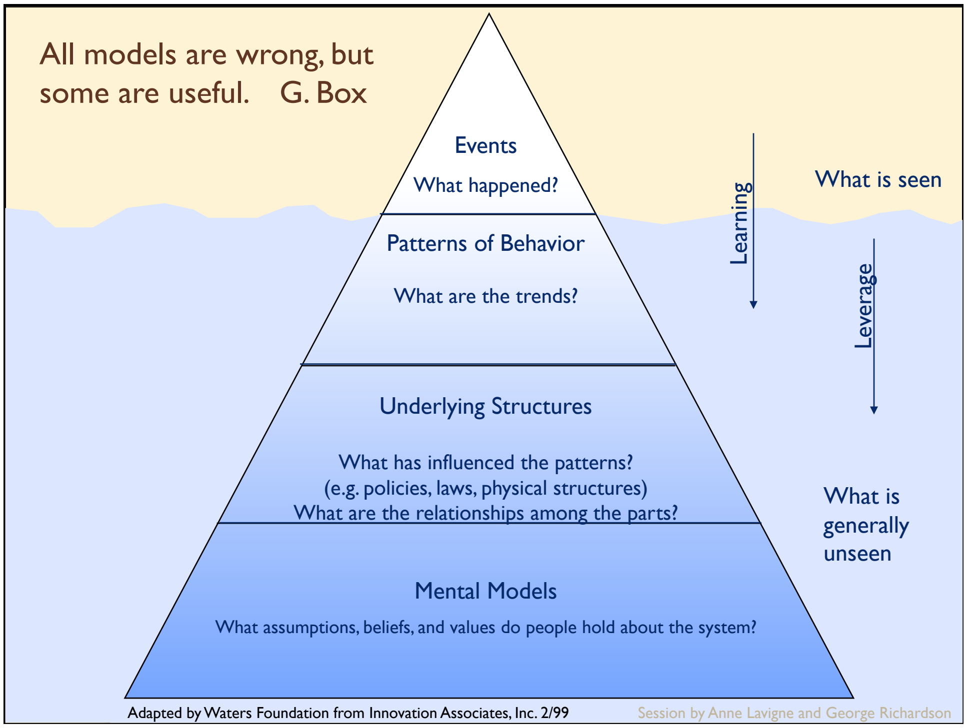
Some quotes to consider when creating models:

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

Clock by Tim Wetherell, Image by OpheliaO, Wikimedia Commons,Public Domain



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.

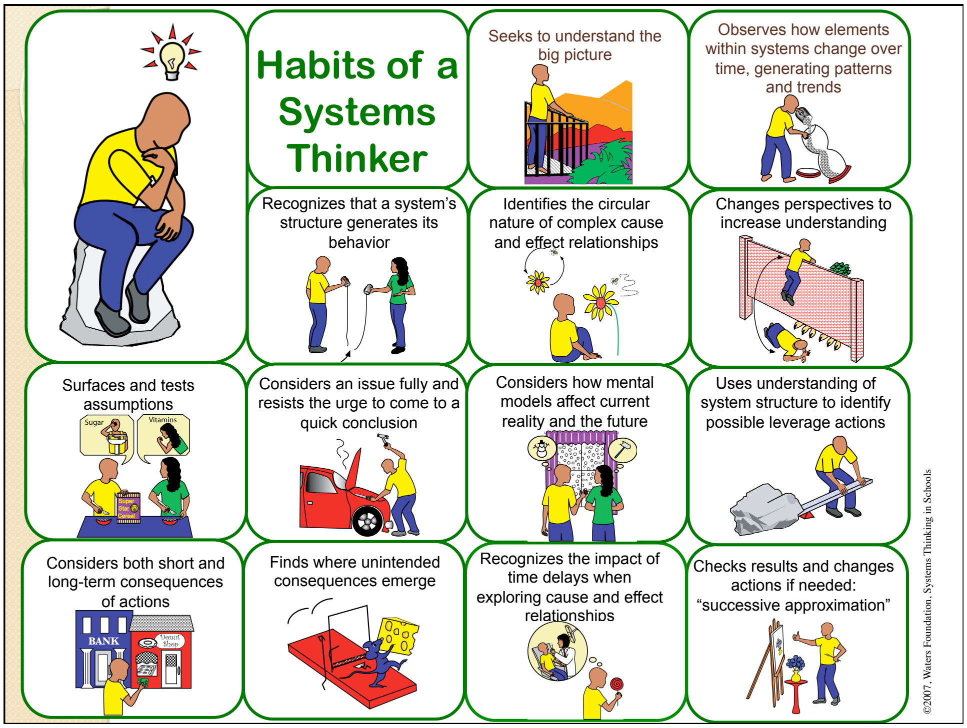
Language Arts Identify, analyze, and apply knowledge of the structures and elements of literature.

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)



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)

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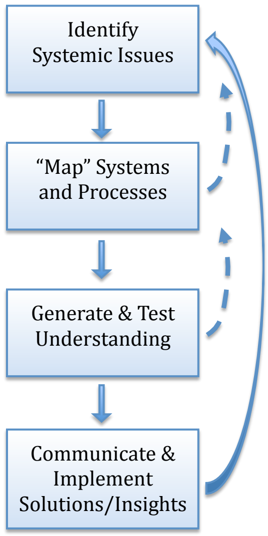
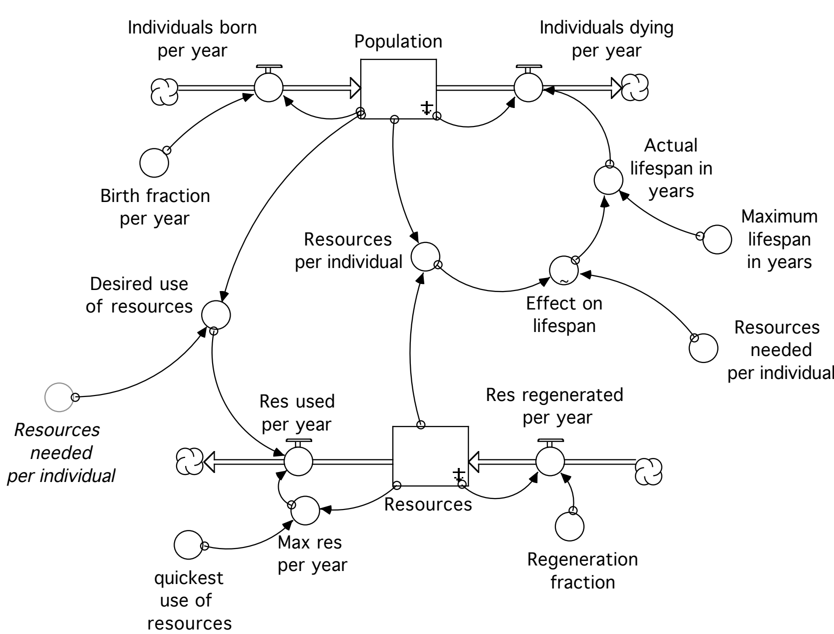
Systems Thinking Process with Concepts to Consider



- 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



6/26/10

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Additional Resources

Online Modeling Resources and Tutorials

- Introduction to Systems Dynamics, US Department of Energy, Online Book Description: This online book was written to introduce system dynamics, a powerful methodology for framing, understanding, and discussing complex policy issues and problems.
- STELLA Tutorials: These flash tutorials demonstrate how one would use STELLA® to construct a Population model showing the dynamics between population size and available natural resources.
- Road Maps: a guide to learning system dynamics The System Dynamics in Education Project (SDEP) was a group of students and staff in the Sloan School of Management at the Massachusetts Institute of Technology, working under the guidance of Professor Jay W. Forrester, the founder of system dynamics from 1990 to 2003. Together, they created the Road Maps Course. Note that Road Maps materials reference less recent modeling software versions, and so some technical details may differ. A few of the included lessons are described below.
- System Dynamics in Education: The First Steps - A 59-page tutorial covering basics of systems dynamics and the use of STELLA II software with many illustrations. The tutorial can serve as a hands-on introduction to system dynamics and learner-centered learning for educators and others interested in learning the basics of system dynamics through computer modeling.
- Beginner Modeling Exercises - Exercises in modeling constant flows. Develops understanding of the basic stock-and-flow structure through examples taken from a wide variety of systems.
- Introduction to Feedback - Introduces the concepts of reinforcing and balancing feedback within a computer modeling context.
- Vensim PLE Quick Reference and Tutorial This is a 23 page reference in pdf format for Vensim PLE, Version 5.4d, including short tutorials on using Vensim PLE to construct causal loop diagrams, stock-and-flow diagrams, and simulation models. Created/maintained by Craig Kirkwood, Arizona State University

Additional Resources

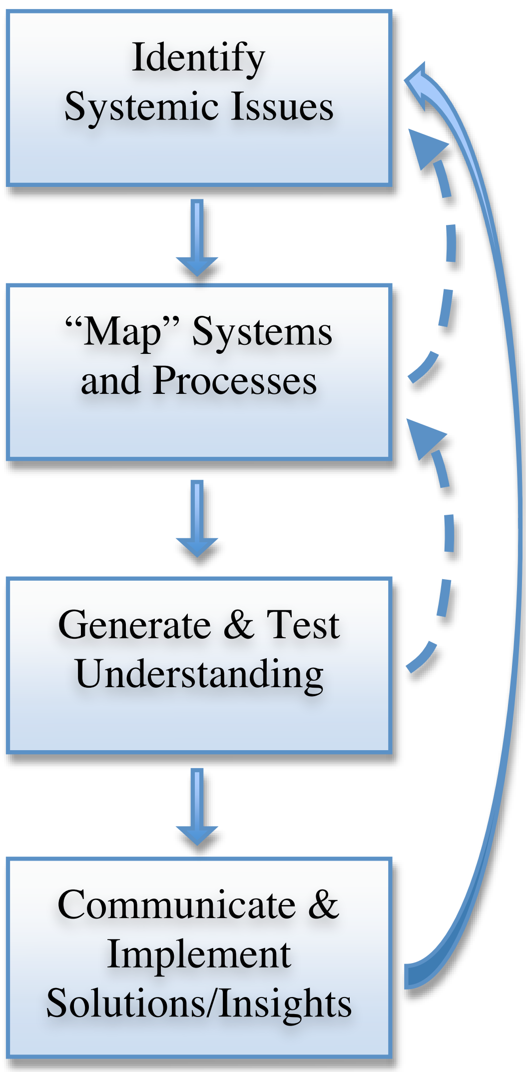
Online Modeling Courses

- 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



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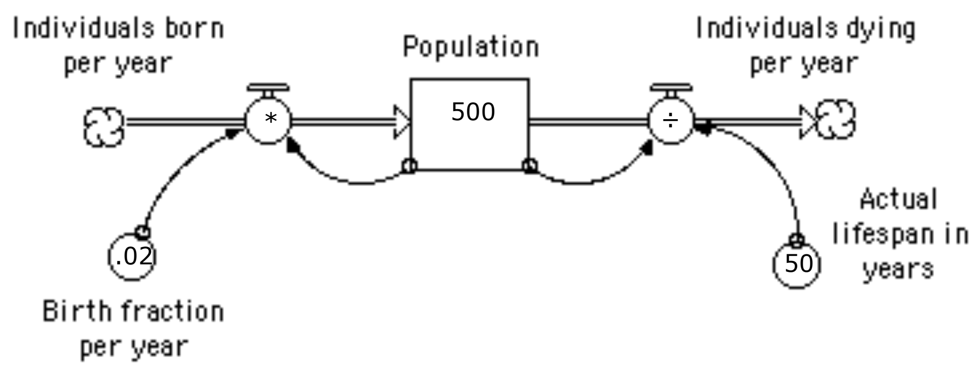
2009 Systems Thinking in Schools, Waters Foundation
Adapted from isee systems and Pontifex Consulting

Populations and Resources

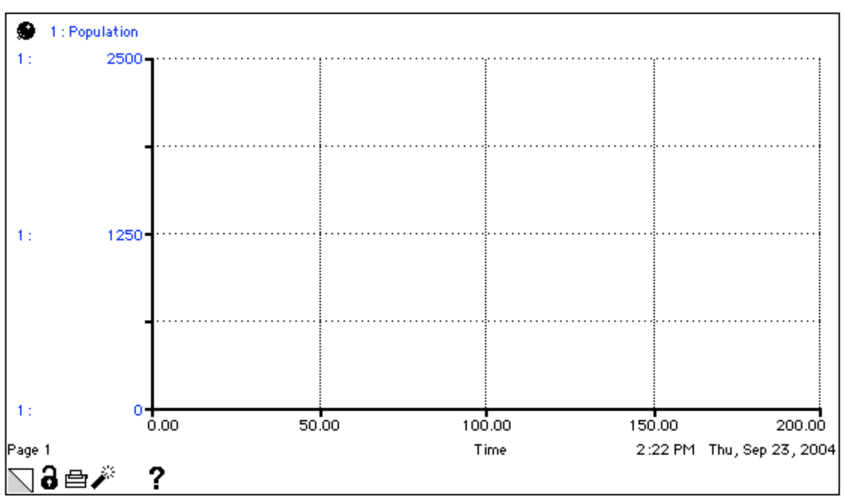
Overview: This task will focus on building a simple population model and then adding in a stock showing the resources on which the population depends. You could think of these resources in many different ways. Resources could be food the population needs to survive, habitat (e.g. trees), or energy (e.g. 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.

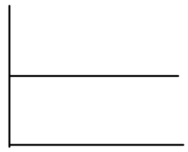


- Create a graph for the population. Notice on the graph that the simulation will run for 200 years.
- Set the scale for the population to be from 0 to 2500.



<u>Journal Entry 1:</u> 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:  <u>Journal Entry 2:</u> Why is the line flat?

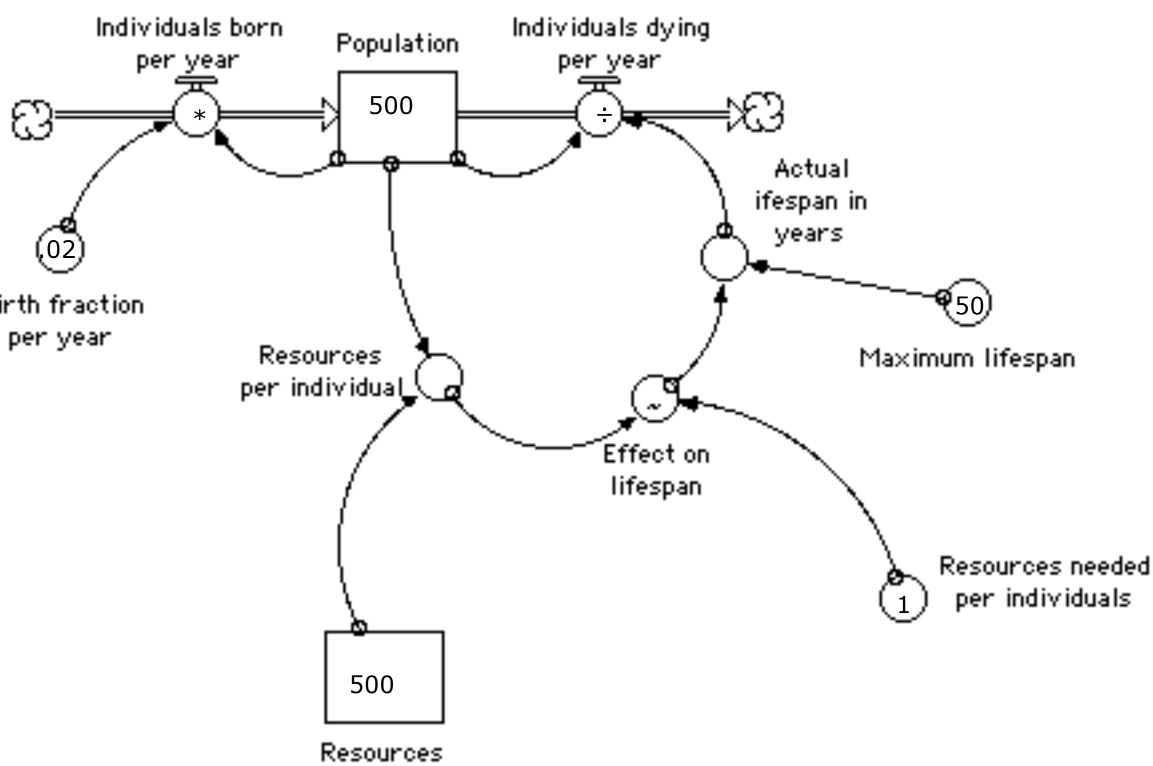
- What do you think would happen if the lifespan were 80 years? 30 years? Run some experiments and then respond to the next journal entry.

  <u>Journal Entry 3:</u> 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?

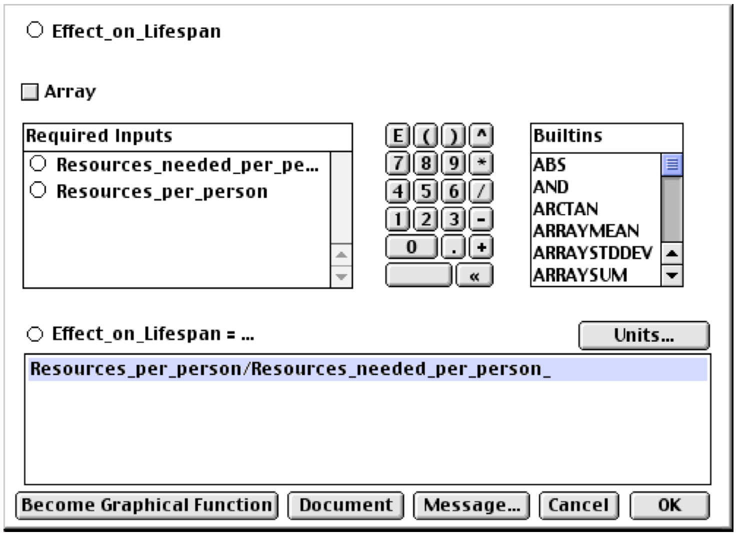
Part II: Adding Resources
You're now ready to build Resources into your model. The amount (stock) of resources will directly affect the population.

- <u>Journal Entry 4:</u> 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.

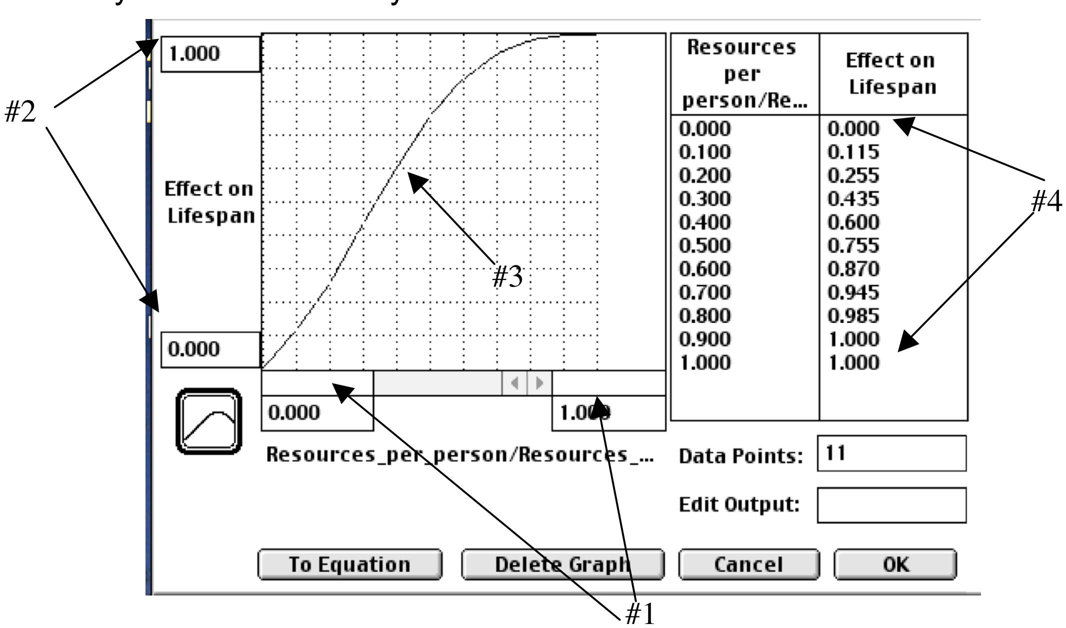


- The model now shows that the amount of resources in a stock will affect how long individuals live. Each individual needs 1 resource. If the "resources per individual" goes below 1, then the lifespan will also go down. To show this in STELLA, we need something called a graphical relationship. It will 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:

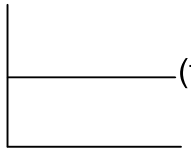
1. The scale of resources per individual/resources needed per individual should be from 0 - 1. (This gives us a fraction of how many resources we have, compared to how may resources we need.)
2. The scale of how lifespan will be effected should also be 0 - 1. (This shows how much the lifespan will be 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:



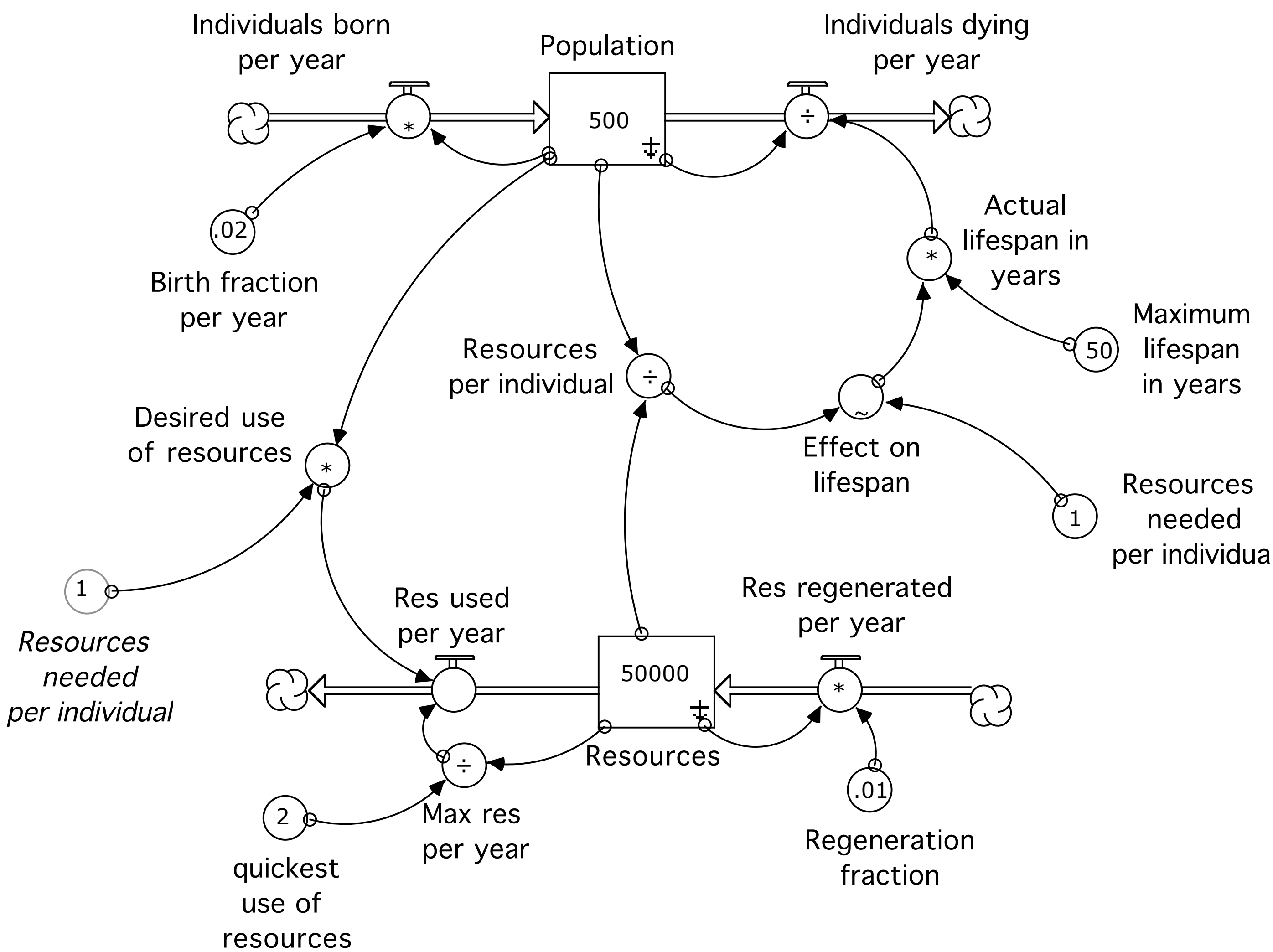
  Journal Entry 6: Why is the line still flat? (type response)

- 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

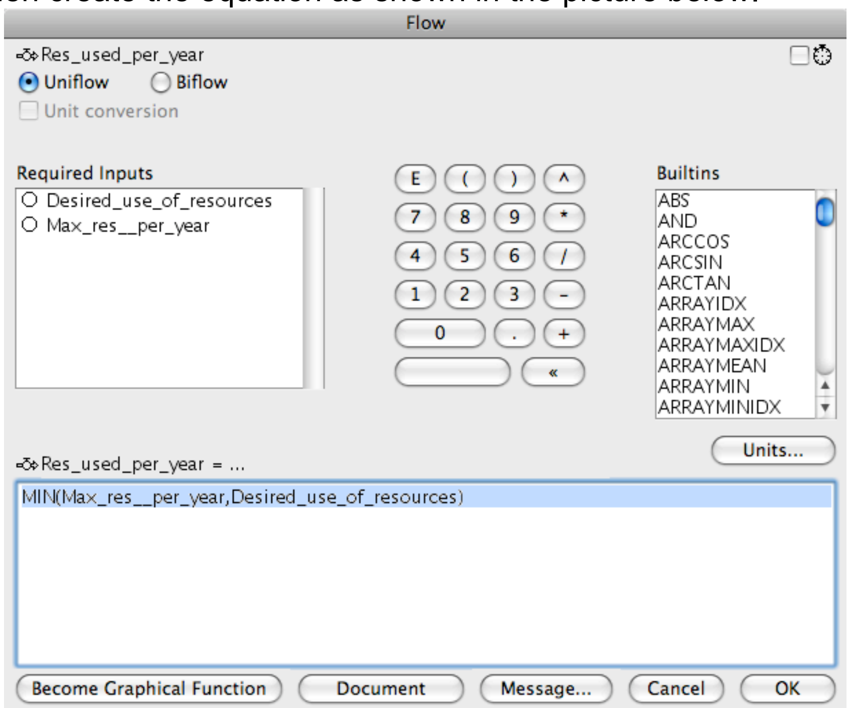
You may have noticed that the stock of resources cannot go up or down because there are no flows. Expand your model as shown below. Note that you’ll need to create a duplicate of “Resources needed per individual” with the ghost  tool.



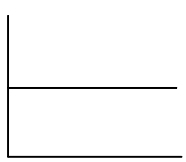
At this point, you should notice that there's still one question mark (?) left inside of "Res used per year." There's a special equation that needs to be put into that outflow. Notice that there's an arrow that goes from the stock of resources to "Max res per year" and then to the outflow. Why are those 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.



- Journal Entry 8: Describe the modifications to the structure (stocks, flows, converters, connecters) 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…?

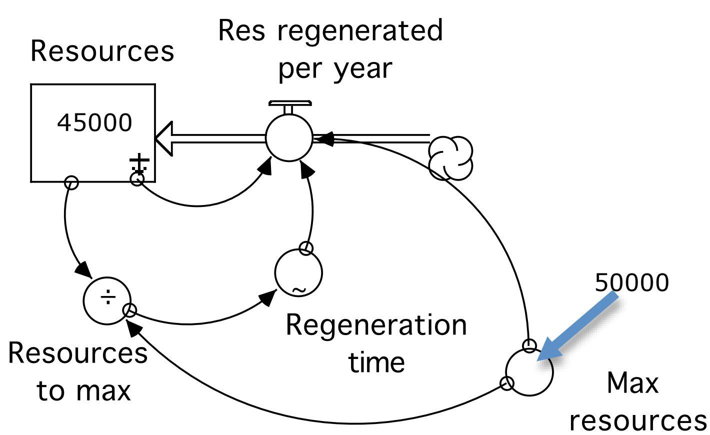
- Journal Entry 10: Explain what you observed and learned from your "What if?" experiments. Consider possible curricular connections.

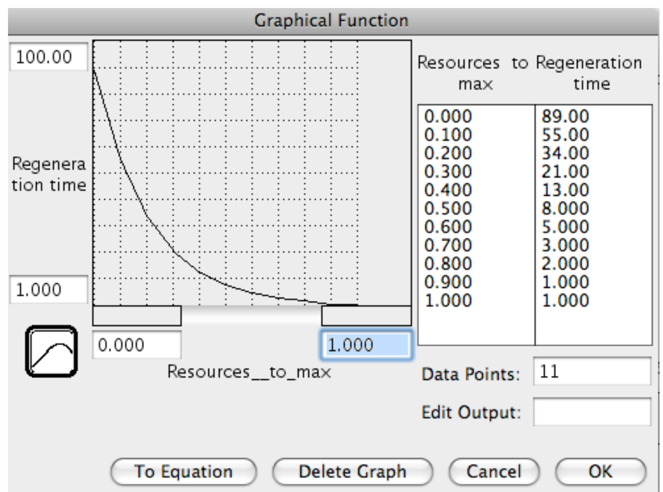
Challenging the boundaries of the model:

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: (Max__resources-Resources)/Regeneration_time





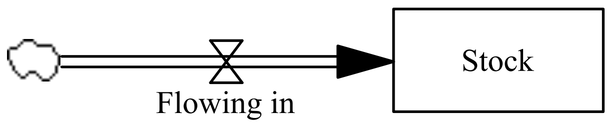
Run the model and try some different scenarios to determine whether or not the resources still grow indefinitely? If not, why? How is the new structure impacting the pattern that you see?

Consider how this model might be useful:

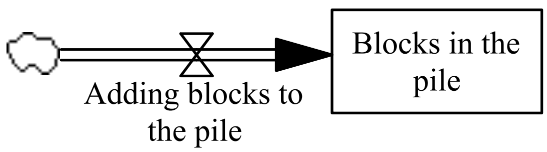
- to learn basic stock/flow structures.
- to learn the basics of modeling.
- to explore how accumulations impact one another.
- to study how populations impact resources and vice-versa.
- to explore reinforcing and balancing feedback.

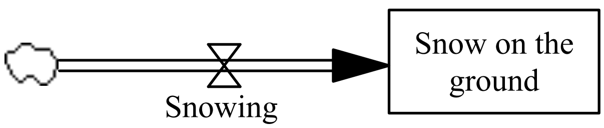
Building Block Models

Simplest stock and flow structure (no feedback):



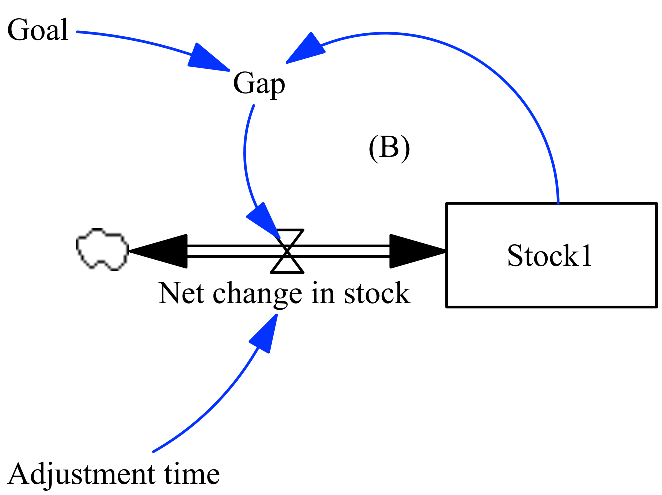
Examples:





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

Simplest balancing loop with an explicit goal:



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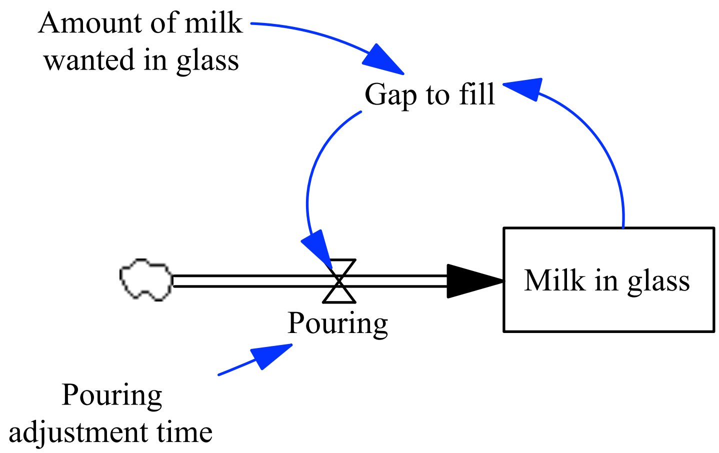
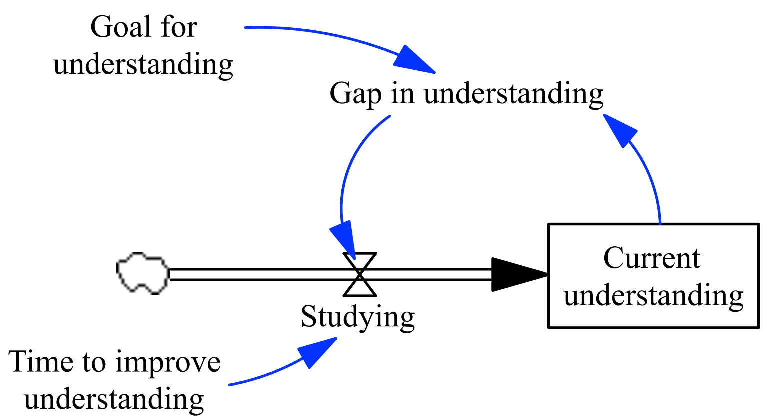
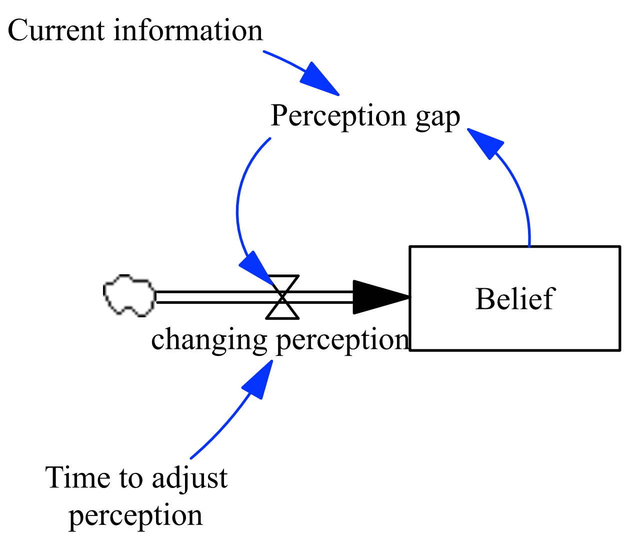
Examples:







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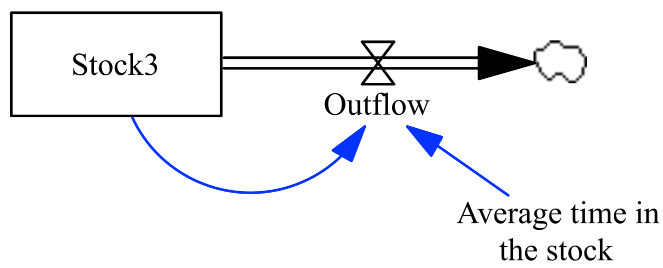
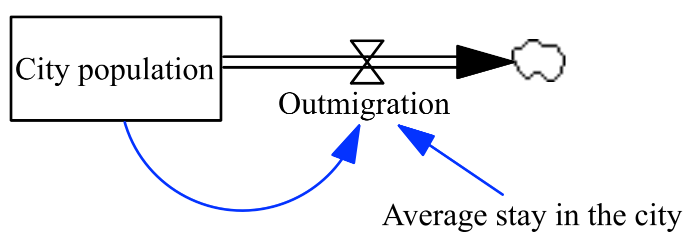
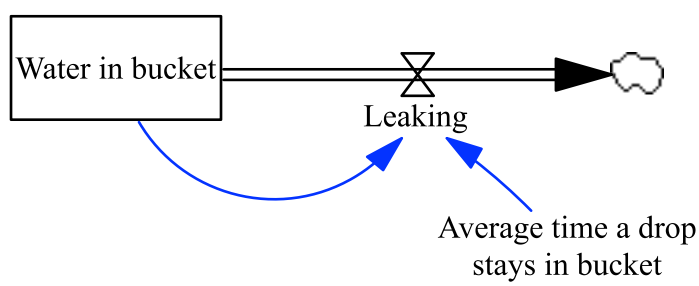
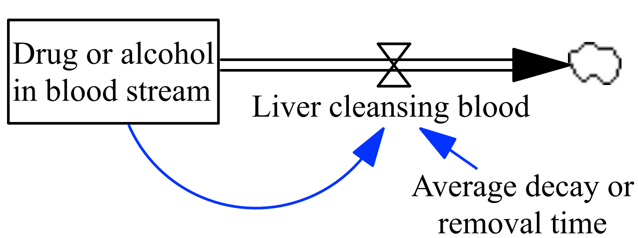
Simplest balancing loop with an implicit goal (zero):



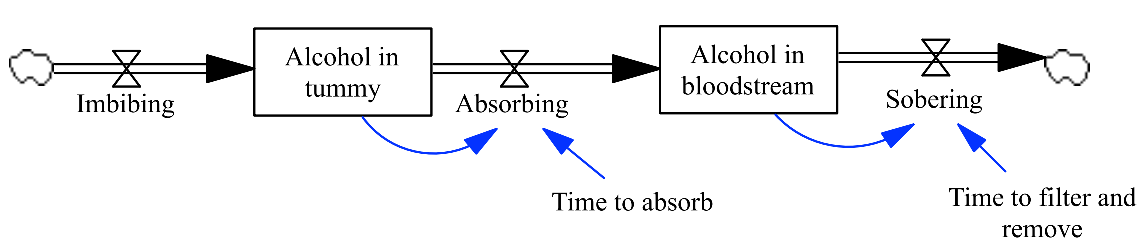
Examples:







Putting two together:



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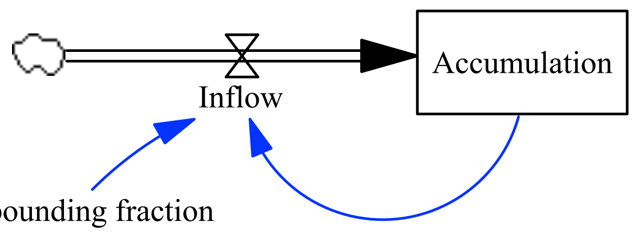
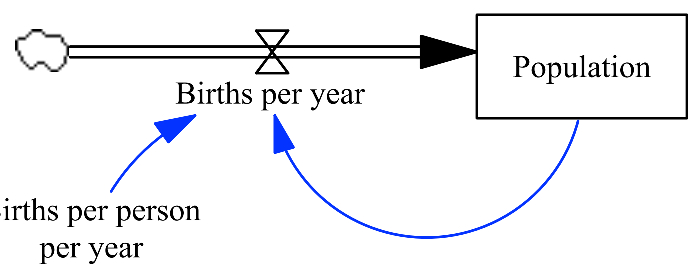
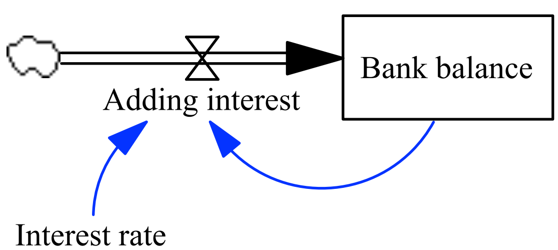
Simplest reinforcing Loop

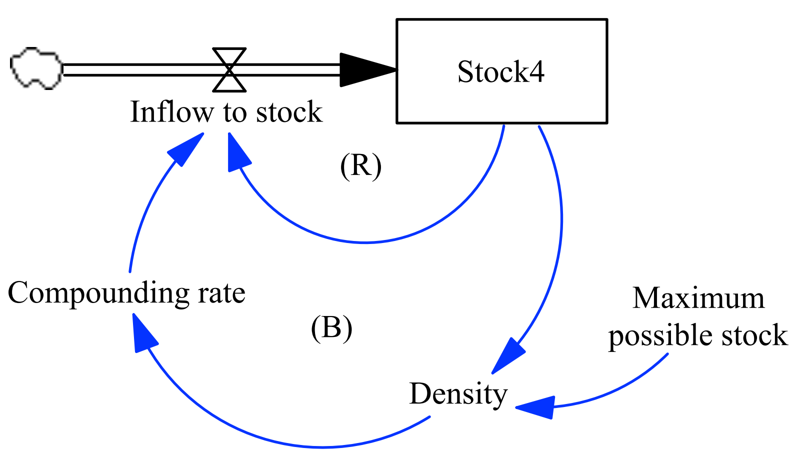


Examples:





Simplest nonlinear system:



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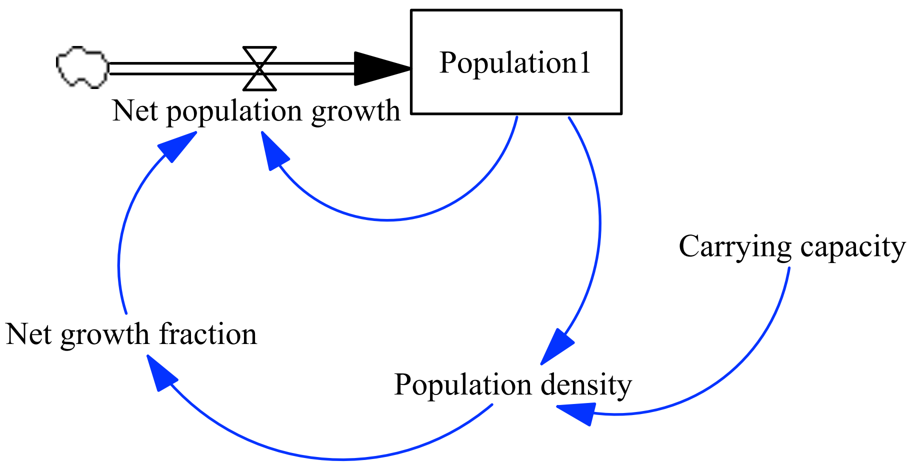
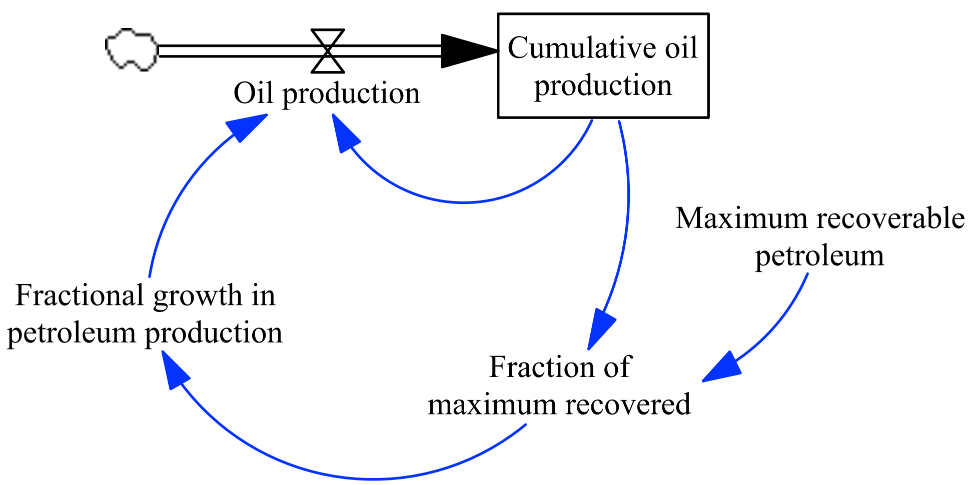
Examples:





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Simulation All current simulations/models are available at www.stinschools.wikispaces.com	**Possible Contexts**	**Lesson Available**	**Source of Simulation**
Bank Model	Generic Models, Math	No	Systems Thinking in Schools, Waters Foundation (STIS-WF)
Coin-Bank simulation with other similar scenarios	Generic Models, Math	No	STIS-WF
Cooling coffee simulation with another similar scenario	Generic Models, Math, Physics, Economics	No	STIS-WF
Fishing Game	Science	No Fishing Game instructions Introduction Videos Earth Education Online	William A. Prothero, Ph.D.
Homework Simulation	Goal Setting	Yes	STIS-WF
Infection Simulation	Generic Models, Math, Science, Social Studies	No	STIS-WF
Infection simulation with other similar scenarios	Generic Models, Math, Science, Social Studies, Classroom Management	No	STIS-WF
Mystery Disease	Math (probability)	Mystery Lesson.pdf MD_Handout_online.pdf Profiles.pdf	STIS-WF
Napkin-fold simulation with other similar scenarios	Generic Models, Biology, Ecology, Math, Personal finance, Social Studies	No	STIS-WF
Population Simulation	Generic Models, Math, Science	Yes (embedded in simulation)	STIS-WF
Populations-Birth Fraction and Lifespan	Generic Models, Math, Science, Social Studies	No	STIS-WF
Renewable and non-renewable resources	Generic Models, Biology, Ecology, Social Studies	No	STIS-WF
Shoe Simulation	Generic Models, Math	No	STIS-WF
Smoking Simulation	Health, PE	No Smoking_Handout.pdf	STIS-WF
The Giver Simulation	Literature, Social Studies	Yes	STIS-WF
Thermostat control simulation with other similar scenarios	Generic Models, Biology, Ecology, Math, Physics	No	STIS-WF

Information on Systems Thinking

Waters Foundation Contacts:

Systems Thinking in Schools - Arizona Center, Waters Foundation
Tracy Benson (520) 745-4588 email: tbenson@pimaregionalsupport.org
Anne LaVigne (520) 745-4588, email: a.lavigne@watersfoundation.org
Sheri Marlin (520) 745-4588, email: s.marlin@watersfoundation.org
Waters Foundation website: www.watersfoundation.org
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. iseesystems.inc. 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:

Fisher (2001, 2004). *Lessons in Mathematics: A Dynamic Approach* and *Modeling Dynamic Systems: Lessons for a First Course* (respectively) http://www.iseesystems.com/store/BookPackage.aspx

Kauffman, Jr., Draper L. (1980). *Systems One: An Introduction to Systems Thinking* (S.A. Carlton, Publisher, 612-920-0060)
http://www.amazon.com/Systems-One-Introduction-Thinking/dp/9996280519

Kim, Daniel. *Introduction To Systems Thinking*, ISBN 188382334x, www.pegasuscom.com

Meadows, Donella H. (2008). *Thinking in Systems, A Primer* (White River Junction, VT: Chelsea Green Publishing): http://www.chelseagreen.com/bookstore/item/thinking_in_systems:paperback

Quaden et al. (2004, 2007). *The Shape of Change* (Acton, MA: Creative Learning Exchange). 2 Volumes. ISBN 0-9753-169-0-7 http://www.clexchange.org/shapeofchange/

Richmond, Barry. *The "Thinking" In Systems Thinking: Seven Essential Skills***.** ISBN 188382348x, www.pegasuscom.com

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Generic Model/Simulation

Generic Structure/Pattern	General
	Connections to Life:
	Lesson Title
	Grade Level
	Subject
	Related Standards/Objectives

Lesson/Assessment Outline