Using the SD Process to Teach STEM and Common Core Math & Science

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Agenda

- STEM Education and STEM Benchmarks
- Common Core Mathematics and Science
- Why System Dynamics?
- Learning Theory
- Grades 9 - 12
  - System dynamics models in algebra, physics, biology
Integrative STEM Education

♦ “… ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others.”

♦ grounded in the tenets of constructivism

♦ inherently learner-centered and knowledge-centered

♦ learn using context of real-world problems

♦ provides for the social interaction so critical to the learning process

“STEM, STEM Education, STEMania,” by Mark Sanders, The Technology Teacher, Dec/Jan 2009
STEM Benchmarks

- **Science**
  - **Scientific Inquiry** – physical science, life science, earth and space science
  - **Personal and social perspective** – population, natural resources, environmental quality, natural and human-induced hazards, global challenges

- **Technology**
  - **Enhance learning**, increase productivity, collaborate constructing technology-enhanced models
  - **Solve problems, make informed decisions in the real world**
STEM Benchmarks

- Engineering
  - Apply knowledge of mathematics, science, and engineering
  - Design and conduct experiments – and analyze data

- Mathematics
  - Use mathematical models to represent and understand quantitative relationships – analyze change
  - Apply and adapt a variety of appropriate strategies to solve problems
  - Understand how mathematical ideas interconnect and build on one another to produce a coherent whole
  - Use representations to model and interpret physical, social, and mathematical phenomena
Common Core Math

♦ Construct Functions
  ♦ Model & compare linear, quadratic, exponential patterns
  ♦ Describe qualitatively the functional relationships between two quantities.
  ♦ Interpret functions in terms of the situation they model.

♦ Modeling
  ♦ Links classroom math to everyday life, work, and decision-making.
  ♦ Models can shed light on math structures.
  ♦ Model cycle: identify variables, form model, analyze and draw conclusions, interpret results, validate conclusions.
  ♦ Making math models is a Standard for Math Practice.
Common Core Science

- Crosscutting Concepts (5 of 7)
  - Patterns: guide organization & study factors in relationships
  - Cause & effect: Mechanisms and explanations
  - Structure and function
  - Stability and change: rates of change of a system
  - Systems and system models
    - Defining a system under study
    - Specifying boundaries
    - Making an explicit model of the system
    - Testing ideas/understanding ideas
    - Feedback
Why System Dynamics?

- System Dynamics: focused on the study of the **internal behavior of systems** in our lives and the world

- Based on **feedback theory** and circular causation analysis

- Uses **computer simulation** to test mental models of how a system works

- Eases the **transfer of concepts/models across disciplines** (due to generic structures and software)
Learning Theory

- Student-centered lessons (active learning mode)
  - Test “what-if” scenarios
  - Extend the model to incorporate new ideas
- Uses visual representation
  - Useful with a *broad* audience of students
- Emphasizes conceptual understanding
- Multi-disciplinary problems
My Sequence of Extra Lessons

- Motion Detector
Motion Detector

Linear

Parabolic
Motion Detector

Linear and Quadratic relationships
My Sequence of Extra Lessons

- Motion Detector
- Theory of Finite Differences
Theory of Finite Differences

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Linear
## Theory of Finite Differences

### Linear

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### Quadratic

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My Sequence of Extra Lessons

- Motion Detector
- Theory of Finite Differences
- STELLA Models
My Sequence of Extra Lessons

- Motion Detector
- Theory of Finite Differences
- STELLA Models

  - Simple generic types – match traditional problems
    - Coordinate diagram and equation
    - Experiment with model structure
  
  - Introducing feedback
    - Writing– explaining circular causation
  
  - Extending problems to new situations
The Software: STELLA

- Stock
- Flow
- Converter
- Connector
Linear Function Model

Constant Inflow or Constant Outflow

Money in Shoebox

deposits per month
Quadratic Function Model
Linear Inflow or Linear Outflow

Displacement

Velocity

acceleration

vel
Oscillatory Behavior with the Motion Detector
Simple Oscillation Model
Harmonic Motion

Displacement

Velocity

acceleration

vel
Simple Oscillation Model

Harmonic Motion

Displacement

Velocity

Acceleration

Displacement

Velocity

Acceleration
Exponential Model: Reinforcing Feedback

Money in Bank

Interest added per month

Monthly interest rate

Money

Months
Exponential Model: Reinforcing Feedback

Money in Bank

interest added per month

monthly interest rate

Money

months
Exponential Model
Balancing Feedback

- Amount of Radioactive Substance
- Amount lost per week
- Weekly decay rate

Graph showing the decrease in amount of substance over weeks.
Exponential Model
Balancing Feedback

Amount of Radioactive Substance

Amount lost per week

weekly decay rate

amount lost per week

Amount of Radioactive Substance

weeks

Amt. Substance

6/12/12
Population Model

Exponential Growth and Exponential Decay

births → Population → deaths

birth rate → Population → death rate
Two Population Model

rabbit birth fraction

Rabbit births

Rabbits

Rabbit deaths

rabbit death fraction
Two Population Model

Rabbit births

Rabbits

Rabbit deaths

Wolf deaths

Wolves

Wolf births

Rabbit birth fraction

Rabbit death fraction

Wolf birth fraction
Two Population Model

Rabbits

- Rabbit births
- Rabbit deaths

Wolves

- Wolf births
- Wolf deaths
- Wolf Death Rate

Area

Rabbit density

Rabbit kills per wolf

Rabbit birth fraction

Rabbit death fraction

Wolf birth fraction
Two Population Model
Teaching a Year-Long System Dynamics Modeling Course in High School
Course Objectives

- Prepare students to identify and analyze problems in the world from which they can gain understanding by building and analyzing SD models.

- Develop skill in model building, in analyzing model design and output/feedback, and in explaining what they learn.
Screening for Tay-Sachs

How Does Genetic Screening Affect a Closed Community Afflicted with the Tay-Sachs Disease?
by Charles Runckel and Ben Zimmerman

Two students:
Age 16 years
Portland’s Traffic

Three students: ages 15 years
Reforestation in Oregon

Two students age 16 and one age 17
Student Reflection  Franklin High School (1999)
CC Modeling Systems

- View Student Work
  - model diagram, paper, video presentation
- Link System Dynamics to National Education Standards
- Resources and Research
Why System Dynamics?

- It gives us a chance to understand that
  - Cause and effect are not closely related in time or space
  - Low leverage policies are usually ineffective
  - High leverage policies are usually difficult to apply correctly
  - The cause of the problem is within the system
  - There is conflict between short-term and long-term goals
  - There is a tendency for goals to spiral downward
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“Coming to an understanding of systems must be a participative experience. Computer modeling allows an accelerated vicarious experience. …immersion in such active learning can change mental models.”

Jay Forrester
Resources

♦ Diana Fisher
  ♦ diana.fisher2@frontier.com
  ♦ www.ccmodelingsystems.com

♦ Creative Learning Exchange
  ♦ www.clexchange.org

♦ Systems Thinking in Schools
  ♦ www.watersfoundation.org
Thank You

System Dynamics Modeling: A Different Way to Think

“We cannot solve our problems with the same thinking we used when we created them.” — Albert Einstein