Experience 21st Century Learning
Using Information Communication Technologies
Presented by Mark Williamson
Oslo International School

A System Dynamics Example
Presented by Peter Heffron
Oslo International School

Nordic Network of International Schools Conference
20—21 April 2013 Gothenburg, Sweden

Introduction to System Dynamics in K-12 Schools Guide & Tutorial

Link to PowerPoint: http://sdrv.ms/10Apsjf
**ICT & MINI-SYSTEM DYNAMICS (SD) WORKSHOP PLAN**

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Introduction to System Dynamics in K-12 Schools

Guide & Tutorial

Even the simplest systems concepts help

Donella Meadows
Introduction to System Dynamics in K-12 Schools by Peter Heffron is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported License.

Based on a work at http://sdrv.ms/10Apsjf.
Warning...

This is **not** a “presentation”

...It **is** a guide and tutorial, so please...

Jump around, explore, and have **fun** with system dynamics!
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What is system dynamics?

*Systems dynamics* is a methodology to explore complexity, interconnectedness, and change over time.

- Developed at MIT in the late 1950s
- First introduced in a K-12 school in 1975 (USA)

Source: *System Dynamics and System Dynamics* pdf
www.clexchange.org/.../CommonCoreStandards
2. THE SYSTEMS DYNAMICS LANGUAGE: STOCK-FLOW EXAMPLE
(‘FEEDBACK’ OMITTED FOR SIMPLICITY—FOR NOW)
Thanks to the (2009) revised science and environmental sustainability education standards* in the Washington State (USA) K-12 system, teachers are now required to teach and assess children's understanding of systems.  *Standards hyperlink

As parents, systems educators, and Washingtonians, we have been on a learning journey ... to find out more about how we can help support the teaching of system dynamics in our state's classrooms.

K-12 Science & Social Studies Curriculum
Model Source—next slide

Ref: http://blog.pegasuscom.com/Leverage-Points-Blog/bid/32605/Weaving-Systems-Thinking-into-the-K-12-Curriculum
“Systems thinking is one of seven 21st century skills that we embed throughout our curricula. It is a K-12 science measurement topic and also shows up in our K-12 social studies curriculum at all levels under the measurement topic, ‘Patterns of Change Over Time.’ You can access our curriculum information on our CFSD website's home page at www.cfsd16.org

Click on the "21st Century Learning" tab at the top of the page. From there you can see all kindergarten through 12th grade level curriculum documents that show you how the systems thinking component progresses K-12 at each grade level in science and social studies.”

Mary Kamerzell (9 Oct 2012)

Mary Kamerzell, Ph.D., Superintendent
Catalina Foothills Unified School District #16
2101 E. River Road. Tucson, AZ  85718
Tel: 01-520.209.7537
mkam@cfsd16.org
In 1996, Tim Lucas, elementary school principal, Ridgewood, NJ (USA) wrote:

“We are introducing kindergartners to the concepts of stocks and flows and the idea that behaviors can be graphed over time.

Beginning in first grade students are mapping larger sets of information and working with causal loops to explain cycles in nature and everyday events.

Students continue working across the curriculum, strengthening their understandings of behaviors over time, causal loops, and simulations mediated through a systems approach.

By fifth grade, students are manipulating simple computer models that integrate into their curriculum.”

Ref: System Dynamics and K-12 Teachers: a lecture at the University of Virginia School of Education by Jay W. Forrester Massachusetts Institute of Technology Cambridge, MA, USA May 30, 1996
The purpose of this guide is to encourage you—OIS students, parents and teachers—to:

1. **Explore why and how** system dynamics principles, methods, and tools are used successfully in K-12 schools
2. **Experiment** with basic system dynamics concepts inside and outside the classroom
3. **Connect with system dynamics resources for beginners**, including modifiable lesson plans related to standard content areas in all K-12 subjects and grade levels
Navigation Suggestions

1. PowerPoint in Slide Show Mode
2. Do the system dynamics exercise
3. Skim through
4. Re-visit slides as desired
5. See three glorious websites (Appendices)
6. Peruse system dynamics books (OIS Library)
close-to-home system examples

- International education system (2)
- School (3)
- Class in school (4)
- Aquarium in classroom (5)

Credits:
1. Earth: Google Images
2. International Education System: Google Images
3. Oslo International School (Google Earth)
4. Class: Emily Camin:
   http://myportfolio.usc.edu/ecamin
5. Aquarium: Google Images

Ver: 21 April 2013 - ph

Introduction to System Dynamics in K-12 Schools
A System: *Wheatfield with Cypresses* by Vincent Van Gogh

Source: www.vangoghgallery.com/catalog/Painting/747/Wheat-Field-with-Cypresses.html
A challenge...

Balancing an emphasis on specialization and studying parts of things...

with exploration of how those parts interconnect...

while ensuring curriculum standards and learner outcomes are achieved.

System dynamics to the rescue!
‘Laundry List’ versus ‘Systems’ Thinking

We often simply list and prioritize things we want to analyze, such as:

1. People
2. Non-Renewable Resources (oil, coal, gas)
3. Etc.

Barry Richmond called this laundry list thinking; the opposite of systems thinking, shown here...

+ Means a Reinforcing effect (more produces more; less produces less)

− Means a Balancing effect (less results in more; more results in less)

In systems thinking, each element affects the other.
Let’s take a minute to focus on the meaning of the + and the –

**+**

Means a **Reinforcing** effect: 
*More* produces *more*; and *less* produces *less.*  
**Example >>IMAGE1**

**–**

Means a **Balancing** effect: 
*Less* results in *more*; and *more* results in *less.*  
**Example >>IMAGE2**

For fun, try reversing the +/- logic. Does high self-esteem result in lower accomplishment? Does spending money result in more money in the bank?
‘Laundry List Thinking’ versus ‘Systems Thinking’... Applied to teaching and learning (example)

...students, teachers, and parents begin to see relationships like this:

Example from a school textbook
Using the headings on the star diagram, describe how sustainable development might be achieved.

Per our diagram:
1. Is the development element ‘sustainable’? Explain.
2. What might make it more sustainable?
3. What other causes/effects could we include?

From ‘laundry list thinking’...
...resulting in better analysis

and greater understanding

Greater understanding?! Look at all of those relationships! It’s confusing!

At first it can seem confusing. But after a few trys, as with mind-mapping and brainstorming, it becomes second nature.

The advantage? System dynamics is highly visual. Implicit mental models are made explicit and thus easier to share, understand, and critique.
Behavior Over Time Graphs

“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. BOTGs focus on trends.”

Source: www.watersfoundation.org/index.cfm?fuseaction=content.display&id=175
What is the difference between systems thinking and system dynamics?

Systems thinking and system dynamics are two sides of the same coin.

- **Systems thinking** focusses on exploring interrelationships, including creating *causal loop diagrams* and *behavior over time graphs*, without the need for computer software. (*Years K-5 and higher*)

- **System dynamics** employs systems thinking outputs such as causal loop diagrams (above) to focus on building and analyzing stock and flow models—aided by user-friendly computer software such as *Vensim* and *STELLA*. (*Years 5-IB and higher*)
Why is eventual competence in *basic* system dynamics our main goal?

System *dynamics*—which incorporates systems *thinking*—addresses several weaknesses in causal loop diagrams:

- Causal loop diagrams often mix-and show illogical connections between stocks, flows, policy and management issues, etc. *System dynamics models distinguish between stocks, flows, and policy and management issues.*

- Causal loop diagrams are generally unable to show magnitudes (i.e., quantities) and effects of interrelationships over time. *System dynamics models use and produce changed quantities over simulated time, depending on model structure and inputs to-and outputs from-stocks.*
Three (system dynamics) questions:

a) How can we control how much potable water is in the bathtub?

b) Why does it take time to change how much potable water is in the bathtub?

c) Could this bathtub work similarly for people, pollution, energy, ideas, emotions, etc?
Let’s consider a real-life system dynamics challenge:*

*potable water and people*  

*potable water refers to water fit for drinking*
How are these two elements—potable water and people—related?

On a piece of paper, use arrows to show how you feel potable water availability and number of people affect one-another.

Put a “−” sign at the pointed end of an arrow if an increase in people results in a decrease in potable water availability, or if a decrease in people results in an increase in potable water availability.

Put a “+” sign at the pointed end of an arrow if an increase in people results in an increase in potable water availability or if a decrease in people results in a decrease in potable water availability.
But before sketching your response, some thought on the direction of the arrows...

A → B

Arrow Direction Example: ‘A’ affects ‘B’....

So, what if ‘B’ also affects ‘A’? (We would need 2 arrows altogether.)

Does the quantity of people affect the quantity of available potable water?

Does the quantity of available potable water affect the quantity of people?

How?
What is the story here? List your observations.
**The Story** (created, unraveled, and internalized by students, parents and teachers) *may include:*

1. People use potable water
2. *More* people use *more* potable water, and some people use more than others
3. Eventually more people use potable water faster than it is replenished
4. Insufficient potable water to meet peoples’ needs results in *fewer* people through deaths and/or migration
5. Other observations that students and teachers might have

**Questions we might ask:**

1. How long does it take for the bathtubs to fill and empty?
2. How could we make the potable water in the bathtub last *longer*?
3. What other elements affecting and affected by potable water and people might we include in our causal diagram?
What we just did—and what students, parents and teachers of all ages usually enjoy doing—is **systems thinking**... a practical skill that adds value in **all** subject areas and grade levels.

Of course there is more to system thinking—including **system dynamics**, which involves **modeling** (helping students—everyone—explore questions like *How fast do the bathtubs empty and fill over time?*)
Systems Citizens

One of the biggest benefits of using system dynamics in schools, may be the development of *systems citizens* (Barry Richmond):

...*People who have a better capacity and motivation, as citizens, to address the complex real world problems that confront them* (Jay Forrester, MIT, founder of system dynamics).

*Wow! ‘Systems Citizens’ relates to OIS’s *Core Learner Outcomes* and involvement in *Peace Jam*, the *Model United Nations* academic simulation, *volunteer work in Africa*, and more! Cool...*
People do not need to know they are learning about the science of systems thinking and system dynamics.

They just need to be taught, from the beginning, that the world is made of dynamic, interconnected systems and that there are tools we can use to [better] understand these dynamic relationships.

Source: Frank Draper. «Teaching by Wondering Around» in *Tracing Connections* (in the OIS Library)
SUGGESTED NEXT STEPS:

1. Re-visit particular slides if necessary for better understanding

2. Visit the three K-12 system dynamics websites listed in the Appendices

3. Use provided links to other Web resources that apply to your interests

4. Check out some of the system dynamics books, pdfs and DVDs listed in the Appendices

5. Make a personal commitment to try occasionally using a few basic systems thinking methods, such as causal loop diagramming, when analyzing an issue or topic, especially with others—inside and outside the classroom

6. Share your suggestions to improve this introduction to system dynamics in K-12 schools with the author: peter.heffron@gmail.com
The End

Thank you

Art source: The Long Leg by Edward Hopper:
http://media.photobucket.com/image/the%20long%20leg/ahthesun/8a441b46.jpg?o=11

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Please check out the Appendices
APPENDICES

- Systems Thinking in K-12 Schools (websites)
- Systems Thinking Rubrics
- Secondary, Pre-IB and IB Resources (website)
- STELLA modeling software (installed on OIS computers)
- Books, PDFs, and DVDs (OIS Library)
- Testimonials (teachers, students, and administrators)
- Studies Re: system dynamics effectiveness in schools
K-12 System Dynamics

Resources
Our Mission
To develop Systems Citizens in K-12 education who use systems thinking, system dynamics, and an active, learner-centered approach to meet the interconnected challenges that face them at personal, community, and global levels

Spotlight
CLE Books: Dollars and Sense User Survey
Provide us feedback about the Dollars and Sense simulations and lessons! We will use the feedback to improve future editions of the book. As we work to provide a greater range of simulations online your feedback will help guide our process.

If you have already worked with Dollars and Sense, please take the time to complete the user survey. If you have not worked with Dollars and Sense, play with the simulations here.

10th Biennial Systems Thinking and Dynamic Modeling Conference - Registration is open!
The CLE is pleased to announce that we will be hosting our 10th biennial ST/DM conference at the Babson Center in Wellesley, MA from June 30 to July 2, 2012. The theme for the conference this year will be Critical Thinking: Using Systems Thinking and System Dynamics to address the State Common Core Standards and STEM standards.
We will explore best practices for using ST and SD in the classroom and in school systems, using the wealth of ST/SD tools and approaches that can help our students (and adults) think critically about the systems around us and how they change over time. The conversation will include the synergy with Common Core Standards and the STEM process as well as the attitudes and beliefs of systems citizens gained through ST/SD study. Register now! Or learn more...
Systems Thinking in Schools
Waters Foundation

Vision

Our vision is to deliver academic and lifetime benefits to students through the effective application of systems thinking concepts, habits and tools in classroom instruction and school improvement.

Mission

Our mission is to increase the capacity of educators to deliver student academic and lifetime benefits through the effective application of systems thinking concepts, habits and tools in classroom instruction and school improvement.
SECONDARY, PRE-IB AND IB-LEVEL RESOURCES:
CC MODELING SYSTEMS: ccmodelingsystems.com

Good examples, including videos, of secondary school/Pre-IB and IB-level system dynamics projects
HABITS OF A SYSTEMS THINKER

And...

A Related Systems Thinking Rubric
For Teachers (next slide)

Source: The Waters Foundation
www.watersfoundation.org/index.cfm?fuseaction=content.display&id=135
# Systems Thinking Rubric

**Systems Thinking in Schools, A Waters Foundation Project**  
*Systems Thinking Instructional Capacity Rubric*

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<tr>
<th>Focus Areas</th>
<th>Novice</th>
<th>Basic</th>
<th>Proficient</th>
<th>Advanced</th>
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<tr>
<td><strong>Planning</strong></td>
<td>Teacher uses existing lessons obtained from websites, books, training, or other teachers with little to no modification.</td>
<td>Teacher is able, with some assistance, to adapt existing lessons to the curriculum, standards, and specific needs of students.</td>
<td>Teacher independently adapts existing lesson or unit plan to the curriculum, standards, and specific needs of students.</td>
<td>Teacher integrates ST habits (previous slide) concepts and tools into instruction in multiple contexts over the course of the school year. Application of ST is evident beyond specified lesson plans.</td>
</tr>
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</table>
| **Instruction** | There is no evidence that a lesson incorporating ST concepts and tools has taken place. | Teacher requires assistance teaching a lesson incorporating the ST concepts and tools. | Teacher independently teaches an ST lesson without assistance. | Teacher mentors colleagues by:  
1. Inviting other teachers to observe,  
2. Assisting others in planning or Debriefing an ST lesson, and  
3. Observing others and providing feedback on an ST lesson. |
### Focus Areas

<table>
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<tr>
<th>Habits of Systems Thinking</th>
<th>Novice</th>
<th>Basic</th>
<th>Proficient</th>
<th>Advanced</th>
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<tr>
<td>There is little to no evidence that habits of systems thinking are incorporated into lessons.</td>
<td>Teacher refers to habits of systems thinking during instruction.</td>
<td>Teacher refers to habits of systems thinking often and helps students make connections between learning goals and specific habits of systems thinking.</td>
<td>Teacher fosters student ability to independently refer to habits of systems thinking and make connections between learning goals and specific habits of systems thinking.</td>
<td></td>
</tr>
</tbody>
</table>

| Transfer | Little to no evidence of transfer is observable. | During instruction, teacher helps students transfer understanding of how one system operates by comparing it to another system of a different type that operates in a similar manner. | During instruction, teacher asks students to transfer understanding of how one system operates by comparing it to another system of a different type that operates in a similar manner. | Teacher fosters students independently transferring understanding of how one system operates by comparing it to another system of a different type that operates in a similar manner. |

| Student Work Samples | No evidence of ST student work is observable or available. | Teacher representation of student work is shared, as when a teacher draws a visual representation of what students describe. | Teacher shares samples of work illustrating the students systems thinking abilities. | Teacher shares student work with colleagues and actively asks for and offers critique that informs instruction. |

(End)
Reinforcing system dynamics principles with posters ... cards ... etc

Ref: http://pegasuscom.3dcartstores.com/

Students can also make *their own* posters and cards, etc.
### ‘Story-telling’ Model Examples

Right-click on the link, then select *Open Hyperlink*

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<th>Grade Levels*</th>
<th>Title &amp; Author</th>
<th>Topic</th>
<th>Link</th>
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<td>5 - 7</td>
<td><strong>Dollars and Sense</strong>&lt;br&gt;By The Creative Learning Exchange</td>
<td>‘This lesson provides an introduction to linear (constant) saving, linear spending, and simultaneous saving and spending.’ <strong>SAVING &amp; SPENDING</strong></td>
<td><a href="#">Dollars and Sense</a></td>
</tr>
<tr>
<td>4 - 10</td>
<td><strong>Easter Island 1.3</strong>&lt;br&gt;By Heather Skaza (9th Grade Teacher)</td>
<td>Demonstrates the close relationship between a population and its primary resource base over time. <strong>SOCIAL STUDIES, HISTORY, CHANGE OVER TIME, PROBLEM ANALYSIS/SOLVING, ETC.</strong></td>
<td><a href="#">Easter Island</a></td>
</tr>
<tr>
<td>7 - IB</td>
<td><strong>We have met an ally and he is Storytelling</strong>&lt;br&gt;By Chris Soderquist</td>
<td>Illustrates how system dynamics helps understand the complexity of the Afghanistan war. <strong>SOCIAL STUDIES, HISTORY, POLICY ANALYSIS, ETC.</strong></td>
<td><a href="#">Afghanistan</a></td>
</tr>
<tr>
<td>IB</td>
<td><strong>Macro-Economics 101</strong>&lt;br&gt;By Keith Eubanks</td>
<td>‘Allows the economics student to explore how growth in population, the money supply and government spending may affect capital accumulation, income and employment. <strong>ECONOMICS, POLICY ANALYSIS</strong></td>
<td><a href="#">Economics</a></td>
</tr>
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</table>

Many more models of varying quality are available in most subject areas and age levels at [Forio Simulate](#) (Internet).

* Levels are approximate. Many models and the concepts behind them can relatively easily be adapted for different age groups and to contribute to existing Learner Outcomes, etc. Challenging, modifying, or building new models can enhance understanding even more! (ph)
TRAINING RESOURCES

People with system dynamics experience are often available by prior arrangement to:

1. Provide **group and one-on-one orientation** to system dynamics principles, methods, tools, and examples geared to **different age levels/curriculums** (Primary through Secondary School) and/or **subject areas** (Math, Science, English, ESL, History, Social Studies, Economics, International Development, etc.)

2. Prepare and co-facilitate with class teachers, **system dynamics ‘pilot’ exercises** for students, based on a subject/topic they are already studying

**System Dynamics Knowledge Centers and Expertise**

1. There are various SD/ST **experts** around the world, mostly associated with universities—who can often provide additional guidance if/as needed (Google «system dynamics in ‘your country’»)

2. Excellent **online** self-paced orientation to system dynamics basics for students, teachers, principals, and parents—as well as teacher guides, lesson plans, sample models, etc—is also available. **Recommended:**
   - The Creative Learning Exchange: [http://clexchange.org](http://clexchange.org)
   - The Waters Foundation: [www.watersfoundation.org](http://www.watersfoundation.org)
   - CC Modeling Systems: [www.ccmodelingsystems.com](http://www.ccmodelingsystems.com)
   - Forio Online Simulations: [http://forio.com](http://forio.com)
OTHER RESOURCES

Handbook for K-12 Systems Thinking

1 Page Systems Cheat Sheet

http://livebinders.com/media/get/ODYzMTM3

Systems Thinking OVERVIEW

AAAS Definition from Science for All Americans
Any collection of things that have some influence on one another can be thought of as a system. The things can be almost anything, including objects, organisms, machines, processes, ideas, numbers, or organizations. Thinking of a collection of things as a system draws our attention to what needs to be included among the parts to make sense of it, to how its parts interact with one another, and to how the system as a whole relates to other systems. Thinking in terms of systems implies that each part is fully understandable only in relation to the rest of the system.

Dr. Art Sussman: System Definition & Three Systems Questions
A system exists whenever parts combine or connect with each other to form a whole. The whole is QUALITATIVELY more than the sum of its parts. You, your circulatory system, the Earth, the solar system, the galaxy, the universe, and the multiverse, all exist as systems.
OTHER RESOURCES (available in the OIS Library)

INTRO & TESTIMONIALS for Parents, Teachers, Principals

INTRO for Pre-IB-IB Students; Parents; K-12 Teachers; Principals

SD Teacher’s Guide for Secondary School (Student Prerequisite: First Year Algebra) Lessons in the major secondary school disciplines

System dynamics for 3rd-8th Grades —Students, Teachers, Parents

For Secondary School and IB System Dynamics Using Algebra I, Algebra II, Pre-Calculus and Calculus with Applications Across the Sciences
STELLA Software

Accessible on OIS computers*

Use STELLA to:

• Simulate a system over time
• Jump the gap between theory and the real world
• Enable students to creatively change systems
• Teach students to look for relationships – see the Big Picture
• Clearly communicate system inputs and outputs and demonstrate outcomes

* OIS students and staff, upon request, the OIS Learning Technology Coordinator (in coordination with IT) will enthusiastically install STELLA on your computer... and orient you to its use.

Source: www.iseesystems.com
K-12 System Dynamics

Benefits
Does system dynamics make a difference?

Yes...

See the DVD
That School in Tucson
Available in the OIS Library

and studies referred to in following slides
In 1996, Tim Lucas, elementary school principal, Ridgewood, NJ wrote:

“We are introducing kindergartners to the concepts of stocks and flows and the idea that behaviors can be graphed over time. Beginning in first grade students are mapping larger sets of information and working with causal loops to explain cycles in nature and everyday events. Students continue working across the curriculum, strengthening their understandings of behaviors over time, causal loops, and simulations mediated through a systems approach. By fifth grade, students are manipulating simple computer models that integrate into their curriculum.”

Ref: System Dynamics and K-12 Teachers: a lecture at the University of Virginia School of Education by Jay W. Forrester Massachusetts Institute of Technology Cambridge, MA, USA May 30, 1996
Benefits of using system dynamics in schools

1. Students use system dynamics tools to clarify and visually represent their understanding of complex systems.

2. Students use behavior-over-time graphs (BOTGs) to depict their understanding of patterns and trends.

3. Connection circles and causal loop diagrams help students describe their understanding of the connections and interdependencies of complex systems including historical systems, scientific systems, economic systems, cultural systems, political systems, and literary systems, both fiction and nonfiction.

4. Students for whom English is a second language have demonstrated marked improvements communicating their thinking both orally and in writing as a result of using behavior-over-time graphs, causal loop diagrams, and the other systems tools.

5. When students make their thinking visible through the use of systems tools, teachers can immediately identify misconceptions that students may have about curricular content.

6. Students experienced in recognizing and using system dynamics concepts and tools seek out new and varied perspectives when solving problems.

7. When using system dynamics concepts and tools, many students show increased motivation, engagement, and self-esteem.

SOURCE: The Creative Learning Exchange
On a personal level, starting to teach a modeling course, and using STELLA models in my [high school] mathematics courses made me very nervous at times.

I recommend experimenting in certain classes, and telling the students that it is an experiment. Students *love* to try something different.*

The basic concepts about systems can be introduced as early as kindergarten, as described by an elementary school principal:

We are introducing kindergartners to the concepts of stocks and flows and the idea that behaviors can be graphed over time.

Beginning in first grade students are mapping larger sets of information and working with causal loops to explain cycles in nature and everyday events. Students continue working across the curriculum, strengthening their understandings of behaviors over time, causal loops, and simulations mediated through a systems approach.

By fifth grade, students are manipulating simple computer models that integrate into their curriculum.

Ref: System Dynamics: The Classroom Experience—Quotations from K-12 Teachers
By Jay W. Forrester, Massachusetts Institute of Technology, January 29, 2009 (pdf)
Testimonials continued

AP Environmental Sciences Teacher

Secondary School History Teacher

Secondary School Student Modeling Presentations
1. A Computer System Simulation of Student Performance in the Elementary Classroom
   Author(s): Nancy Roberts       Subject: Research
   Link to the file: http://sag.sagepub.com/

2. America Disrupted: Dynamics of the Technical Capability Crisis
   Author(s): Dan Sturtevant       Subject: Research
   PDF (2238 K)

3. Assessing the Effectiveness of Systems-Oriented Instruction for Preparing Students to Understand Complexity
   Author(s): Richard Randall Plate       Subject: Research
   PDF (722 K)

4. Building Slightly More Complex Models: Calculators vs. STELLA
   Author(s): Diana M. Fisher       Subject: Research
   PDF (513 K)

5. Can people learn behaviors of stock and flow using their ability to calculate running total? An experimental study
   Author(s): Tony Phuah       Subject: Research
   Link to the file: https://bora.uib.no/handle/1956/4171

   Author(s): Oren Zuckerman, & Mitchel Resnick       Subject: Research
   PDF (582 K)

7. Concept Learning Feedback Loops
   Author(s): Steve Wilhite       Subject: Research
   PDF (558 K)

8. Does a Model Facilitate Learning? Some preliminary experimental findings
   Author(s): David Wheat, Robin Goldstein, & Larry Weathers       Subject: Research
   PDF (298 K)

9. How Is This Similar to That? The skill of recognizing parallel dynamic structures on center stage
   Author(s): Linda Booth Sweeney       Subject: Research
   PDF (129 K)

10. System Dynamics and Dynamic Modeling within K-12 Schools: Effects on Student Learning
    Author(s): Anne LaVigne       Subject: Research
    PDF (117 K)

11. The Feedback Method: A System Dynamics Approach to Teaching Macroeconomics
    Author(s): David Wheat       Subject: Research
    Link to the file: https://bora.uib.no/handle/1956/2239

    Author(s): Leah Greden Mathews, & Andrew Jones       Subject: Research
    PDF (597)

13. Learning System Thinking: The role of semiotic and cognitive resources
    Author(s): Maria Larsson       Subject: Research
    Link to the file: http://www.lu.se/o.o.i.s?id=12588&postid=1503748

No need to read... Unless you want to see studies regarding the effectiveness of using systems thinking and system dynamics in K-12 schools
K-12 System Dynamics

Introducing to Schools
Introducing system dynamics to schools isn’t easy.

System Dynamics Adoption by Schools (*is hard*)

- **Lessons Learned** *(Sample... More in pdf source below)*
  - We encountered two major hurdles to infusing system dynamics into K-12 education:
    - first, learning system dynamics is hard
    - second, instituting any change in education is even harder
  - Rather than reach out to all teachers, we should have invested all our resources in the innovative early adopters already inclined toward learner-centered teaching, built their SD skills, and developed a larger body of lessons for their students.
  - It is essential for students, teachers and administrators to work together in a spirit of cooperation, creative risk-taking, and learning from mistakes, because students will need that perspective and system dynamics problem-solving skills to deal with the dynamic complexity facing them.

*Source: System Dynamics in K-12 Education: Lessons Learned, Debra Lyneis and Lees N. Stuntz, The Creative Learning Exchange*

K-12 System Dynamics

System Dynamics
System dynamics (SD) is an extension of systems thinking. With SD we can:

- **Model** stocks, flows, and feedback over time
- **Analyze** the possible effects of our (or others’) models given different assumptions, policies, constraints, etc.

To illustrate...
SD Example: Stocks, Flows, Feedback (see ‘connector’)

STOCKS:
- People
- Non-Renewable Resources
- Trees
- Food
- Potable Water
- Land
- Fish
- Carbon Dioxide
- Pollution
- Chickens, Rabbits, Cockroaches
- ‘Happy’ People, ‘Sad’ People
- Bacteria In Petri Dish
- Perpetrators, Victims, Bystanders
- Etc!

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If the STOCK is people:
What affects inflows and outflows of people? (births and deaths; immigration and emigration)

Source: Thinking in Systems (Meadows) – in the OIS Library.
Dynamic Model Example Using STELLA:*

*People and Potable Water*

Results at 20 years

Results at 50 years

* STELLA is a popular, low-cost, ‘visual’ system modeling software package
US-China Project Focuses Student Teams on Real World Problems

Students at the Vermont Commons School in Burlington, Vermont and their peers in Nanjing, China make it look easy to collaborate on complex models of real world issues.

This year, four cross-cultural student teams used STELLA to examine urban sprawl, water quality, maple syrup production capacity, and rocket engine fueling and staging. While email and videoconferencing helped break distance and time zone barriers, STELLA provided teams with a universal language that permitted problem solving while highlighting cross-cultural perspectives.

About the US-China Project

The US-China Systems Science Learning Project is a three-year initiative that teams students in Burlington, Vermont with peers in Nanjing, China to create, design and test solutions to real world problems. Founded by educators at the Vermont Commons School and Nanjing Education Technology Center to ensure that students are learning how to innovate and graduating with solid problem solving skills and experience in international collaboration, the project relies heavily on STELLA, Systems Thinking software.

A case study detailing the US-China Science Learning Project and its use of SystemsThinking and STELLA is now available at www.iseesystems.com/vcs
What is system dynamics?

*System dynamics* is a methodology to explore complexity, interconnectedness, and change over time.

Source: *System Dynamics and System Dynamics* pdf
www.clexchange.org/.../CommonCoreStandards