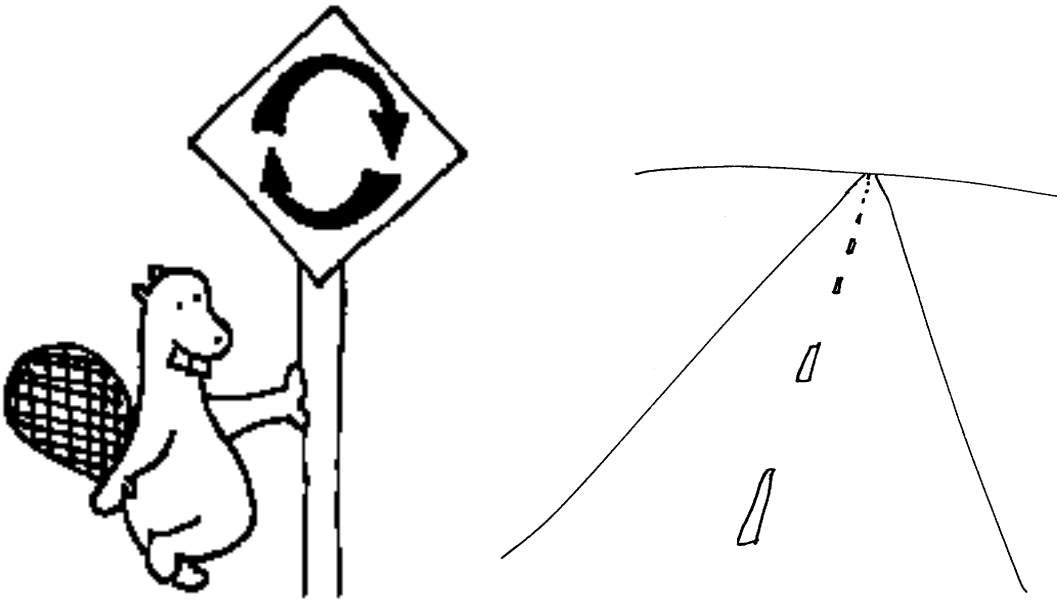
Road Maps 1

A Guide to Learning System Dynamics



System Dynamics in Education Project

Road Maps 1

System Dynamics in Education Project
System Dynamics Group
Sloan School of Management
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August 21, 1992
Latest Revision October 5,1996

Compiled under the direction of Professor Jay W. Forrester

Welcome to Road Maps One!

Road Maps is a self-study guide to learning the principles and practice of system dynamics. Road Maps One is the first in the series of chapters in Road Maps and serves as a general introduction to the field of system dynamics and its applications. We include readings that explain what a 'system' is and show how the concept of 'feedback' is critical to understanding how the components of a system are interconnected. We explore the use of system dynamics in K-12 education, and provide an example from the classroom. Finally, we illustrate the use of system dynamics in understanding the behavior of social systems.

Topics Covered in Road Maps One

An Introduction to Systems

- *Systems 1: An Introduction to Systems Thinking*
  by Draper L. Kauffman, Jr.

System Dynamics in Education

- *System Dynamics and Learner-Centered Learning in Kindergarten through 12th Grade Education* (D-4337)
  by Jay W. Forrester
- *Simulating* Hamlet *in the Classroom* (D-4540-1)
  by Pamela L. Hopkins

System Dynamics and the Media

- *System Dynamics Meets the Press,* (D-4143-1)
  an excerpt from *The Global Citizen*
  by Donella H. Meadows

Policy Analysis in Social Systems

- *Counterintuitive Behavior of Social Systems* (D-4468-1)
  by Jay W. Forrester

Things You'll Need for Road Maps One

Books

You will need the following book for Road Maps One:

Kauffman, Draper L., 1980. *Systems 1: An Introduction to Systems Thinking.*

To order a copy of this book, contact Pegasus Communications (see Appendix).

How to Use Road Maps One

Road Maps One explores several topics in system dynamics through selected readings and exercises. Before each reading or exercise is a short description of the reading and its most important ideas. After each reading or exercise, we highlight the main ideas before moving on.

Each chapter in Road Maps contains readings that introduce and strengthen some of the basic concepts of system dynamics. Other readings focus on practicing the acquired skills through various exercises or simulation games. Most of the chapters conclude with a prominent paper from the literature in the system dynamics field.

We present the fundamental concepts of system dynamics as *System Principles* in Road Maps. These principles are enclosed in boxes that highlight them from the rest of the text to emphasize their importance. The progression of system principles in Road Maps allows you to revisit each principle several times. Each time a principle is revised in Road Maps, you will build upon your previous understanding of the principle by learning something new about the principle. The system principles are the core of Road Maps around which the readings, exercises, and papers are built.

As part of the spiral learning approach that we use in Road Maps, many concepts will be briefly introduced early on and then explained later in greater detail. Road Maps contains a number of series of papers that are spread out over successive chapters. Each of these series focuses on a specific topic in system dynamics or the developing of a particular skill. The series start out with a simple paper, and progress to further develop the idea in subsequent chapters.

Now let's get started!

An Introduction to Systems

The idea of circular feedback in systems is one of the most basic concepts in system dynamics. Systems are built from interlocking feedback loops. The first reading in Road Maps One provides an excellent introduction to these concepts.

- ***Systems 1: An Introduction to Systems Thinking***[1]

by Draper L. Kauffman, Jr.

Systems 1 introduces systems and feedback loops, two important ideas which will be further developed in more readings throughout Road Maps. A strong grasp of systems and feedback loops will build a good foundation for learning more advanced principles in system dynamics.

Please read *Systems 1: An Introduction to Systems Thinking* now.

After reading *Systems 1*...

Systems 1 explained in great detail what a system is. Try to identify some systems that you often encounter. The reading also indicated how a given system might behave because of its internal feedback loops. What effect do positive and negative feedback loops have on a system?

The feedback loops that are diagrammed in *Systems 1* are also known as **causal loops**. The diagrams are known as **causal loops diagrams** or **influence diagrams**. We will see causal loops fairly often during the first few chapters of Road Maps. However, causal loop diagrams are not the only way to represent systems, and in later Road Maps, we will introduce the more powerful method of representing systems through the use of stocks and flows.

Now it's time to introduce our first System Principle. Basic concepts in system dynamics are organized as System Principles in Road Maps. We will be revisiting this system principle later in Road Maps.

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[1] Kauffman, Draper L. J., 1980. *Systems 1: An Introduction to Systems Thinking*, Minneapolis, MN, S. A. Carlton, Publishers, (612) 920-0060, 41 pp. For individual orders, contact Pegasus Communications (see Appendix).

System Principle #1:

The feedback loop is the basic structural element of systems.

See the first diagram on page 26 of *Systems 1: An Introduction to Systems Thinking*. The system is composed of a positive and a negative feedback loop. The other systems on pages 26 and 27 show more complex systems with more feedback loops. Notice the circular structure of the feedback loops. Feedback loops are the building blocks of systems that are linked together to build more complex systems.

Let's move on to some of the applications of system dynamics.

System Dynamics in Education

System dynamics is now extensively used in education. System dynamics and learner-centered learning motivate children to become actively involved in their own education. The next two readings illustrate the use of system dynamics in the classroom.

- ***System Dynamics and Learner-Centered Learning in Kindergarten through 12th-Grade Education***[2]

by Jay W. Forrester

In this paper, pre-college education has been described as "poorly serving the needs of society." Most students are resistant to the methods of teaching currently used by their schools. Forrester, the founder of system dynamics, presents his views on how system dynamics may improve classroom learning. The paper illustrates how the content of education could be changed through the use of system dynamics.

Please read *System Dynamics and Learner-Centered Learning* now.

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2 Forrester, Jay W., 1993. *System Dynamics and Learner-Centered-Learning in Kindergarten through 12th Grade Education* (D-4337), System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology, December 21, 20 pp.

After reading *System Dynamics and Learner-Centered Learning...*

The paper described the benefits as well as the feasibility of implementing a system dynamics framework in pre-college education. How does system dynamics encourage learning? System dynamics provides a framework for the instruction and integration of all subjects. Schools should encourage the students in seeing the world as interconnected, not compartmentalized! What obstacles must be overcome before system dynamics can become an accepted learning tool in our schools? These questions are addressed by the paper.

A Note on the System Dynamics in Education Project

The System Dynamics in Education Project (SDEP) team is a group of students and staff at the Massachusetts Institute of Technology, working under the guidance of Professor Forrester. Road Maps is the current project of SDEP to help beginners as well as more advanced learners in learning about systems and system dynamics. If you would like to know more about SDEP or would like to send us your comments, contact information is provided in the Appendix. We look forward to hearing from you!

The previous paper referred to some of the actual progress being made with system dynamics in the classroom. The next section talks about one such example.

- ***Simulating* Hamlet *in the Classroom*[3]**

by Pamela Hopkins

This paper describes how the concepts of system dynamics were successfully used in a high school literature class. The approach which Hopkins used focuses on learner-centered learning, as described in the preceding paper. This article includes the computer model of *Hamlet* which was used in the classroom; however, understanding the structure of the model is not essential.

Please read *Simulating* Hamlet *in the Classroom* now.

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3 Hopkins, Pamela L., 1992. "Simulating *Hamlet* in the Classroom," *System Dynamics Review*, Vol. 8, No. 1, Winter 1992, System Dynamics Society, pp. 91-98.

After reading *Simulating* Hamlet *in the Classroom...*

In this case, system dynamics and learner-centered learning have helped to transform the classroom environment. System dynamics is being increasingly used in K-12 education. Organizations such as the System Dynamics in Education Project and the Creative Learning Exchange were founded for the purpose of integrating system dynamics into education.

How does this actual classroom experience compare with the predictions and proposals presented in *System Dynamics and Learner-Centered Learning in Kindergarten Through 12th Grade Education*? How might these techniques affect the quality of education? These experiments clearly show the impact that system dynamics and systems thinking could have on education.

System Dynamics and the Media

This next section discusses how the public and the media have responded to system dynamics.

- ***System Dynamics Meets the Press,***[4]
  an excerpt from ***The Global Citizen***
  by Donella H. Meadows

Donella Meadows writes a syndicated newspaper column entitled *The Global Citizen*. She has tried to challenge popular but incorrect ideas about various topics. From discussing global warming to examining the situation that led to the space shuttle accident, the author addresses some of our problematic assumptions about the systems we live in. Many of these problems arise from a lack of understanding of basic system dynamics concepts. Her efforts have produced some interesting results. In this reading, some of her experiences in dealing with the public, the mass media, and system dynamics are described.

Please read *System Dynamics Meets the Press* now.

After reading *System Dynamics Meets the Press...*

The article makes a strong issue of challenging people's internal models, or paradigms. Through the newspaper column, Meadows has tried to challenge

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4 Meadows, Donella, 1991. "System Dynamics Meets the Press," *The Global Citizen*, pp. 1-12, Washington, DC, Island Press.

some of the common misunderstandings people have about economics, the government, and other social and natural systems. Why is it so important to challenge these paradigms?

Thinking back to Forrester's paper, do you see how a K-12 education in systems could help accomplish this very same goal? How does a system dynamics background help one to understand these areas? How could understanding system dynamics help the public make more informed choices in their own lives?

Social Systems, Policies, and Misunderstandings

The next section addresses the problems that arise in social systems, and explains why people are often mislead by the behavior of complex systems.

- ***Counterintuitive Behavior of Social Systems***[5]

by Jay Forrester

This paper explains that well-intentioned policies intended to help cure social problems often fail to do so. On the contrary, they sometimes worsen the situation they were intended to improve. How can such contrary results happen? Such policies are derived from unclear mental models. These mental models are insufficient for understanding complex social systems, and decisions based on them are likely to do more harm than good. Computer simulation models is then offered as a method of understanding and approaching these systems.

The paper takes a look at two system dynamics models and discusses the unexpected behavior that can arise in multiple-loop feedback systems. It is not necessary to understand the intricacies of the models nor the hypothetical situations explored in the middle of the paper. However, it is important to observe that these computer models can shed light on important social problems, and may have significant impact on how people view the systems around them.

Please read *Counterintuitive Behavior of Social Systems* now.

After reading *Counterintuitive Behavior of Social Systems*...

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5 Forrester, Jay W., 1971. "Counterintuitive Behavior of Social Systems," *Technology Review*, Vol. 73, No. 3, pp. 53-68. Also appears as Chapter 14, pages 211-244, in the author's *Collected Papers* 1975; and as Chapter 1, pp. 3-30, in *Toward Global Equilibrium: Collected Papers*, 1973. Dennis L. Meadows, ed., both from Portland, Oregon: Productivity Press.

System dynamics has much to offer in social sciences such as economics, urban planning, and politics. Policy makers have historically drawn from their own intuitions for their policies, but their intuitions often point to the wrong solutions. These mistakes are not necessarily caused by incompetence or malice, but because people cannot accurately simulate a complex system in their heads. With the world becoming increasingly complex, the need for new tools is clear. System dynamics can become such an effective tool to deal with the complex systems.

Finishing off Road Maps One

Road Maps One was an introduction to systems, to the discipline of system dynamics, and to the concept of feedback loops. What is a positive loop? A negative loop? Why are they so important in system dynamics? Road Maps One also presented our first system principle, that the feedback loop is the basic structural element of systems.

We also covered readings that discussed some of the applications of system dynamics. Its uses in education and the social sciences are becoming widespread. How does it help students learn? How does system dynamics achieve learner-centered learning?

To learn more about system dynamics, please continue on to Road Maps Two. Road Maps Two will get you started on creating your first actual model, and start discussing the basics of computer simulation and system models.

Key Terms and Concepts:

Causal Loop Diagrams
Circular Feedback
Computer Simulation
Influence Diagrams
Learner-Centered Learning
Mental Model
Negative Loop
Paradigm
Policy
Positive Loop
System
System Dynamics

Appendix: Names and Numbers

- To obtain additional copies of Road Maps, please visit our System Dynamics in Education home page on the World Wide Web at:
  http://sysdyn.mit.edu/

  If you do not have access to the World Wide Web, you can buy paper or disk copies of Road Maps through:
  Lees Stuntz
  Creative Learning Exchange
  1 Keefe Road
  Acton, MA 01720, USA
  Phone: (508) 287-0070
  Fax: (508) 287-0080
  Email: stuntzln@tiac.net

- For information on the System Dynamics in Education Project, please visit our home page, or contact:
  Nan Lux
  System Dynamics in Education Project
  System Dynamics Group
  E60-383
  Massachusetts Institute of Technology
  30 Memorial Dr.
  Cambridge, MA 02139, USA
  Phone: (617) 253-1574
  Fax: (617) 252-1998
  Email: nlux@mit.edu

- To inquire about educational prices for STELLA II software, please contact:
  High Performance Systems
  45 Lyme Road
  Hanover, NH 03755, USA
  Phone: 1-800-332-1202 (product inquiries)
  (603) 643-9636 (customer support)
  Fax: (603) 643-9636
  Email (for customer service, tech support and product questions): support@hps-inc.com
  WWW Site: http://www.hps-inc.com/

- Although Road Maps is written specifically around the STELLA II software, two other software applications are suitable for use with Road Maps, assuming the user is willing to make some interpretations and translations:
  Powersim for PC:
  Powersim Corporation
  12030 Sunrise Valley Drive, Suite 300
  Reston, VA 22091, USA
  Phone: (703) 391-2779
  Fax: (703) 391-2768
  Email: powersim@powersim.com

Vensim for PC or Macintosh:
Ventana Systems, Inc.
149 Waverley Street
Belmont, MA 02178, USA
Phone: (617) 489-5249
Fax: (617) 489-5316
Email: vensim@world.std.com
A free "Personal Learning Edition" of Vensim can be downloaded from:
http://news.std.com/vensim/

- If you have any questions about obtaining books required for Road Maps, please contact their respective publishers:

  Chelsea Green Publishing Co.
  P.O. Box 130
  Post Mills, Vermont 05058
  Phone: 1-800-639-4099

  Pegasus Communications, Inc.
  Order Dept.
  P.O. Box 120 Kendall Square
  Cambridge, MA 02142-0001
  Phone: (617) 576-1231
  WWW Site: http://www.pegasuscom.com/

  Productivity Press
  P.O. Box 13390
  Portland, OR 97213
  Phone: 1-800-394-6868, (503) 235-0600
  Fax: 1-800-394-6286
  WWW Site: http://www.ppress.com/

- **Road Maps HELP line:** If you are having any problems with the material in Road Maps, or if you have any helpful comments or suggestions, please email:
  rm-help@sysdyn.mit.edu
  outlining your problem. We will respond as soon as possible.

- To join the K-12 Discussion Group for educators interested in using System Dynamics to teach, email Nan Lux, discussion group administrator, at **nlux@mit.edu**