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Getting Started with Behavior Over Time Graphs: Four Curriculum Examples

Prepared with the support of the Gordon Stanley Brown Fund by Gayle Richardson with Debra Lyneis

This paper will show how behavior over time graphs are used in a fifth grade curriculum, in language arts and social studies lessons. It will explain in detail how and why to use and teach behavior over time graphs, as well as how they lead to the use of other system dynamics tools. Causal loop diagrams are also included. Although this paper will focus on fifth grade language arts and social studies lessons, this curriculum approach and the specific behavior over time graphing instructions apply across all curriculum areas and all grade levels, K-12.

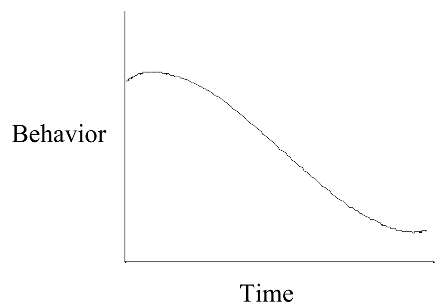
Why Use Behavior Over Time Graphs?

- Behavior-over-time graphs help students focus on patterns of change over time rather than on single events.
- They help students think about the underlying causes of those changes.
- Behavior-over-time graphs make for very engaging work and lively discussions as students begin to think more deeply about what is happening and why.
- Graphing gives students another way to express and communicate their ideas.
- Behavior-over-time graphs can be used throughout the curriculum, across all subjects and grade levels.
- Behavior-over-time graphs prepare students for further work in system dynamics by developing their dynamic thinking skills and their graphing skills.

How to Get Started

The Graph

Behavior over time graphs are easy to start. Nearly everyone has some knowledge of basic line graphs, even young elementary students. The one important thing to remember about a behavior over time graph is that "Time" *must* run along the horizontal axis. The "behavior," the variable that changes over that time, is plotted on the vertical axis. This is *always* true. The purpose of the graph is to picture how the behavior changes as time progresses. Time can be in any unit that fits the behavior: seconds, hours, days, years, etc.



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Modeling in the Educational Environment - Moving from Simplicity to Complexity

by Ron Zaraza, Tim Joy, and Scott Guthrie

For many educators, dynamic modeling is a seductively exciting approach to exploring problems. It allows formerly unapproachable problems to be addressed. It brings the power of numerical results (although sometimes of questionable validity) to disciplines and problems that normally are non–quantitative. Further, it allows a problem to be explored in exhaustive detail without having to do lengthy and involved calculations – the computer and software do the drudge work; the modeler merely designs and outlines the process. Using higher level software like PowerSim and STELLA, even the little computer programming done is fairly simple compared to traditional line–code based software.

These factors lead teachers to adopt model building and model use practices that may actually be counterproductive:

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Updates . . .

Summary of the October K-12 listserve question: What are the three-to-five MOST CRUCIAL, *BEGINNING* CONCEPTS to focus on when introducing dynamic modeling to students?

Some light reading for the days ahead. Many thanks to all for the wonderful response and thoughtful ideas.

Nothing Gold Can Stay
Nature's first green is gold,
Her hardest hue to hold.
Her early leaf's a flower;
But only so an hour.
Then leaf subsides to leaf.
So Eden sank to grief,
So dawn goes down to day.
Nothing gold can stay.
-Robert Frost

As my son and I raked the broad leaves of our tulip tree into neat piles, I was meditative, as is usually the case in Fall—a time for considering the passing solar year, how time permeates the mundane. The leaves turn color, then fall-slowly at first; then, it seems the tree simply sloughs its entire foliage in a few days-especially after a strong rain, and now a handful of leaves hold on. In so short a time, the leaves went from the tree to the lawn. I was seeing stocks and flows, all the while imagining pulses and graphs in my head. For a humanist, this was terribly disconcerting; I'd rather Robert Frost were coursing through my thoughts. Still, I was attentive to nature in a new way; the systems modeling was becoming real.

Of the messages people submitted, this notion that modeling replicates the real was a quiet surprise and gave voice to the recurring ideas of the month: simplicity, clarity and variety.

Many ancillary ideas surfaced in the postings. I'll mention those ideas at the end.

From the Director . . .

As the Holiday season approaches, it is always a good time to reflect upon joys and blessings. I think of the wonderful people whom I have grown close to while all of us pursue the goals of helping to encourage learning which will create a sustainable world. Consistently this fall there are small indications that others are feeling the small but persistent waves we are making—a call here, an e-mail there, saying that they have heard that the use of system dynamics is becoming more widespread in K-12 education.

Our listserve conversation so expertly compiled by Tim Joy is another example of the synergy which has become the norm in our work together.

Thank you, dear friends, for your companionship on the journey. I hope that your holidays are joyous and that you have the peace to reflect on your blessings during this season.

Lees Stuntz (stuntzln@tiac.net)

SIMPLICITY

- Use the simplest structures and a variety of them. It may be a sound idea to use the computer less than one is inclined to early on, thus allowing (forcing?) students to work through the seminal ideas at a human, rather than electronic, pace.

- How do we get students to see the most rudimentary pieces of a system; that is, can they see, as Jay Forrester points out, there are two concepts only: an accumulation and a rate?

- Start with BOT graphs. Students should be able to picture, to visualize, what they wish to model, have a sense (even if uninformed) of a behavior they are undertaking to model.

- Feedback loops (and therefore all systems) consist of two and only two concepts-levels (accumulations or stocks) and rates (flows).

- Introduce the idea of a system very well, what is and is not, what is feedback, and working through predictions of "behavior over time" graphs of various simple examples before getting students onto the computers at all. Sometimes we get in too much of a hurry to use the modeling tool … before we should. The thought processes should be exercised first.

- VERY simple introductions are possible, if not preferable.

- Students need to understand basic graph shapes and the stories they tell.

- Defining boundaries of a system: what are you looking at and what the limits are.

- Bath tub model is an excellent starting model owing to its simplicity and universality. We can all get this one.

CLARITY

- We ought not be surprised that clarity was frequently mentioned, as it truly is at the core of modeling and systems. But it is more than a product of this world view; it is a habit of mind. Beyond or as a consequence of the model building,

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The Variables

The behavior can be anything that increases or decreases over time. For example, it can be the amount of money in a bank account left to accumulate interest, temperature measurements in an experiment, or the number of people or bacteria in a changing population. In these examples, dollars, degrees, and numbers of people are plotted on the vertical axis.

However, there are also many other important variables which increase and decrease over time which cannot be measured in conventional units such as dollars and degrees. For example, some might include a character's self-esteem or happiness throughout a story, the colonists' mounting willingness to fight in events leading up to the American Revolution, or changing morale or team spirit in a school. These "soft" variables can also be plotted and examined.

For soft variables, setting the scale on the vertical axis takes a little bit of discussion to define the variable and its units. For example, in a fairy tale like Cinderella, Cinderella's happiness is an important variable that can be graphed. To quantify it, students could describe the pit of unhappiness as the way Cinderella felt as a poor, dirty, abused charmaid in the beginning. Call that "0 Happiness." At the other extreme is her perfect bliss when she marries prince charming. Call that "10." In between, Cinderella's happiness rises and falls as events unfold and a pattern on the graph emerges. (For young students, you could define the scale as "Low," "Medium," and "High" if that is easier for them than assigning numbers 1 to 10.) The same idea applies to all other variables that do not have conventional measured units. You can plot staff morale on a scale of 1 to 10 as easily as you can plot temperature in degrees from cold to hot. A behavior over time graph can be used to plot and explore *any* change.

Equipment

Behavior over time graphs require no special equipment. They are drawn freehand with pencil and paper or chalk and blackboard. In some cases, students may need graph paper, but try to avoid getting too stuck on lots of details. Remember that the idea is to focus on patterns of change rather than on isolated events or little details.

How to Teach a Lesson Using Behavior Over Time Graphs

Behavior-over-time graphs can be used in any curriculum area whenever you want students to think more deeply about what they have learned, whether it is a story in literature, a topic in social studies, or a science experiment. In any case, it helps to lead students through a series of steps in the discussion until they develop this thinking skill on their own. These are questions to guide the graphing and the discussion:

1. *What is changing?* If you look at the story or the historical developments or the experiment, what is changing over time? What is going up or down?
   - Brainstorm a list of these changes and write them down. Once they get started, students have no trouble generating lots of variables, both hard and soft.
   - Ask students to look for the underlying currents of change rather than just the events. What do they see increasing or decreasing with time?
   - From the list, focus the discussion on those variables that are most important and central to the issues you want the students to explore.
   - At first, you may want to choose one variable to graph together as a class. Or, you might ask students to work individually or in groups on either the same variable or on several different variables.

2. *How is it changing?* Help students to draw their graphs and make sure that their graphs actually depict what they want them to say. For example, if they say something is going up, the line on the graph needs to be going up. This may take practice for some at first.
   - It may help students to label important points on the line, like "Fairy Godmother comes."
   - It also helps to define the axes together. How long is the time? What is the variable and what do low and high values of it mean?
   - Once a graph is drawn, as a class, look at the line on the graph. Is the variable going up or down? Is it changing rapidly or slowly? Does it start out in one direction and then change direction? Does it level off or keep fluctuating?
   - The idea is to identify the *pattern* of the behavior, not every little detail. Students are learning to "read" the graph and think about the change it describes.

3. *Why is it changing?* Now students start to think about the behavior itself. If something is going up, what is happening in the story or experiment to keep it going up? Why did it start to speed up, or go down, or level off? Try to look within the system itself for the causes of the behavior. For example, a population would keep growing more quickly because as people have children, those children have even more children, and so on, until it becomes too crowded and the growth levels off. Causal loop diagrams flow from this discussion.

4. *Why is it important?* What difference do these changes make to the rest of the story? How could it have turned out otherwise? By this point, you won't need any prompting. Students will take off with this discussion and delve deeper and deeper into what happened and why.

5. *What are the relationships?* What are the most important variables and how

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do they relate to one another? If students plotted more than one variable, how do their graphs compare? Does one rise as the other falls, for example? If you plotted only one graph at first, does it suggest a graph of another variable? The idea is to see how the parts of the system fit together, to think about what causes what.

6. *Can you be more specific?* So far, behavior-over-time graphs have taught students to look for patterns of change and try to understand their causes. For more advanced students, the next step is to use the other system dynamics tools: stock and flow diagrams, and computer modeling. These tools lead to an even deeper understanding of the behavior and its causes because students must be more specific about their assumptions. Starting with behavior-over-time graphs, all of the system dynamics tools build on one another. Yet, in the end, a computer model produces its own behavior-over-time graph to read. Teaching students to use behavior-over-time graphs prepares them for the next step.

These questions guide the discussion, but it all rolls pretty quickly as soon as students get involved. The steps may all flow together or have varying emphasis. Sometimes you may not go through all the steps depending on the age and background of the students, the nature of the lesson you are teaching, or the time available.

It helps to specify the first three questions with the students: "What is changing?" "How is it changing?" "Why is it changing?" The remaining questions get addressed as you direct the lively discussions that ensue. With practice, students very quickly identify what is changing and draw their graphs to show how it is changing. *Be very sure to give them enough time to explore the "Why" in depth.* This is the most important part. Remember that the goal is not just to draw a graph but to go as far as you can to teach students to *think* this way.

Advice and Encouragement from Gayle Richardson

Gayle Richardson teaches fifth grade at the Lawton Elementary School in Ann Arbor, Michigan. Her classes represent a very diverse population of students, both ethnically and academically. Gayle was first introduced to system dynamics at a district modeling workshop several years ago. The workshop focused on district-wide planning issues. Gayle was intrigued by this approach but somewhat daunted and unsure how she could use these tools, until she tried behavior over time graphing with her students. After she did it once and saw how eagerly her students just jumped into the discussion, she was hooked. She has continued to learn and develop lessons using these tools.

Gayle has been supported in these efforts by her school principal, Nanette Gill, who had also become very interested in system dynamics in K-12 education. Working with Nan has been invaluable, says Gayle; it has helped to have someone with whom to discuss ideas and obstacles as they both tried this new approach to education. Gayle encourages other teachers to work together on this. She also offers more advice:

- My students love doing behavior-over-time graphs. We use them in all of our subjects. Kids learn best when we get them started and then "get out of their way." If you introduce this to your students, they will love it too.
- You will never understand it as fast as the kids do, so don't wait until you understand everything to teach it to them. Just trust the kids and yourself, and go with it! Kids are natural learner-centered-learners and systems thinkers. As their teacher, you are their guide, but you can learn along with them too.
- Relax! As adults, "getting it right" is important to us, but to kids it is not that big a deal. Kids are very willing to try something and learn from their mistakes. If they draw a graph or a causal loop diagram and it doesn't work, they just erase it and try something else until it does. Kids easily generate graphs and loops. They are just as quick to recognize flaws and try again. This is a good learning experience, so let them go at it.
- Be sure to allow enough "think" time. Kids need less time to draw graphs as they get used to the process, but they still need time to think more deeply and discuss their ideas. This is critical to the process; impatience is counterproductive.
- Resist the urge to graph every little event or be too particular about details. You want students to be looking for broad *patterns* of behavior not isolated events. Think of the big picture. We are teaching kids to play with ideas, not details. It took me a while to get used to this, probably because we have always been so tied to details. Maybe it's a mistake you have to make in order to learn behavior-over-time graphing, but try to move beyond it as soon as you can.
- Don't be intimidated by something new. At first, system dynamics seemed just too difficult. I thought I could never get it. Now I see that behavior-over-time graphs are great for kids and we use them all the time. Meanwhile, I am still learning. This year we are using a computer model in a literature unit too.
- I hope these sample lessons will help you get started too. (Ed. Note: Just 1 sample lesson is included here.)

SAMPLE LESSON: "The People Could Fly"

Curriculum Areas: Language Arts and Social Studies. This lesson uses behavior-over-time graphs and causal loop diagrams in a class discussion about a black American folktale, "The People Could Fly."

Objectives: Children will identify the patterns of change that unfold with the story line. They will learn how black American slaves used folktales to pass on their history and values. Children will gain a deeper understanding of slavery from a slave's perspective.

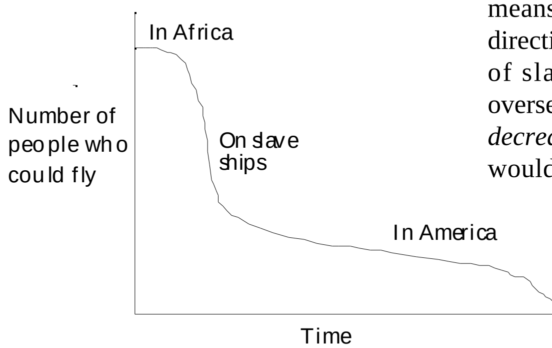
Materials: Paper, pencils, The People Could Fly: American Black Folktales, told by Virginia Hamilton, illustrated by Leo and Diane Dillon, Alfred A Knopf, NY, 1985.

Time Required: 45 min. to 1 hr. (Allow enough time for the discussion to develop.)

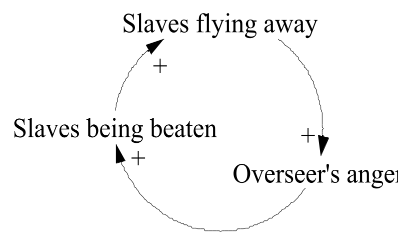
Background: This is a beautiful story at many levels. Long ago in Africa, the people could fly, but with the experience of slavery and the passage of time, many forgot how. One very old slave still remembered. Whenever another slave was severely beaten down by the overseer, this slave would whisper the magic African words to him and that slave could fly away. This made the overseer angry so he would oppress other slaves who would then also fly away to freedom. One day, to avoid punishment, the old man flew away too, leaving behind those who could not remember.

Activity: Read "The People Could Fly" aloud. (It is short, about 5 pages.)

- What changed? Ask students to list things that changed over time in the story and write them on the board. Examples from students: number of slaves on the plantation, number of people who could fly, the master's satisfaction with the overseer, the master's anger, the beating down of slaves. These are the variables. (Remind students to think about "what changed, how it changed, why it changed" by writing these questions on the board.)
- How did it change? Ask students to graph a change in groups or individually. (If this is new to students, you may want to demonstrate one together as a class.) What happened to the number of people who could fly, for example? Help students to be sure that their graphs say what they want them to say.

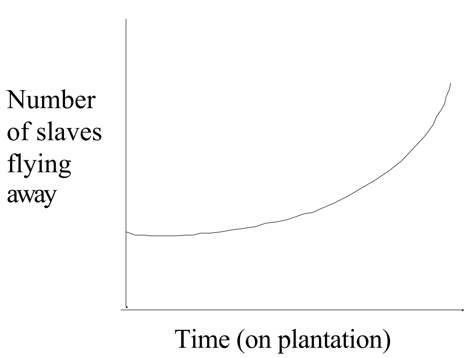


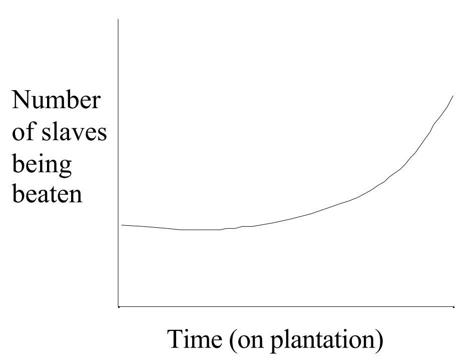
- Why did it change? Ask students to share their graphs and use this as an opportunity to explore the story in depth as they explain their view of what happened and why. Why did the number of people who could fly go down when they were enslaved? Why did it go back up? Children get very engaged in this. You can guide their learning by looking for differing views on the same variable and asking students to explain their own ideas.
- Compare graphs of related variables to find relationships; for example, as the master's anger rises, so does the overseer's cruelty to the slaves, and the number of slaves flying away. Why?
- Ask students to look for causal loops. This may be more difficult for students, but here is one that suggests itself. This causal loop diagram says that the more slaves fly away, the more angry the overseer gets, the more the slaves are beaten, the more they fly away, and so on. Each arrow represents a causal relationship. The plus sign means that the change is in the same direction. An *increase* in the number of slaves flying away causes the overseer's anger to *increase.* (Also, a *decrease* in the slaves flying away would cause the overseer's anger to *decrease.*) This is a positive loop; the behavior keeps spiraling, reinforcing itself.



Note: Older students might delve deeper to see this as a story about slavery, freedom, and the Underground Railroad. Others may go further to explore the relationships between oppression, hope, and the human spirit. The beauty of this discussion approach is that it allows students to explore ideas at a level that is meaningful to them, where real learning can take place.

Note: The entire BOTG article with all 4 sample lessons, called GETTINGR, is available from the CLE and the website http://sysdyn.mit.edu/cle/





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- When building models, teachers tend to begin with models that are too complex. They put in details before they understand how the model truly behaves. As a result, their understanding of model behavior is often questionable.
- To get the "right results" they tend to use converters and involved computation rather than models of real dynamic behavior. Model behavior is controlled by exogenous rather than endogenous factors.
- Teachers often have students work only with completed models, that is, they neither build the model in front of the students nor guide students through building the model. This does not allow students to understand the development of the model. Understanding the development often helps them understand the system the model represents.
- Students may be given detailed instructions for either building or using models that some have characterized as nothing more than "electronic worksheets," little more interesting or effective than the much maligned "dittos." Students complete the task, but what they have learned is not clear.

Perhaps even more dangerous than these questionable practices, however, is the tendency to develop models with an unnecessarily high level of complexity that are then used in whole class or individual student situations. In many cases, these more complex models become little more than "black boxes" in which input values are mysteriously converted to a graph or data table whose values are used to answer questions. These models are difficult to understand because of their complexity.

When used to deal with specific problems, such models do little more than produce numerical results. They often do not aid in understanding the problem's solution. Further, they do nothing to build understanding of the system. When used in activities designed to explore a system, their complexity drives students away from attempting to understand the system. The model diagram is as intimidating as a problem expressed in differential equations would be to the average humanities major. The model confuses through its complexity rather than clarifies through its structure. In spite of these difficulties, the lure of complex, detailed models is powerful. The sense is that greater complexity indicates more accuracy, a better model, more validity, and a more complete understanding of the system involved. While the last trait may be true for the builder of the model, complexity often results in the exact opposite for the user. This reality is a strong argument for adopting a simple rule for both using and building educational models**: Always begin with the simplest model and build complexity gradually, ending with the simplest model that serves your purpose**. And of course, be clear about your purpose. Don't make it too ambitious. Additional complexity may provide ego-gratification, but is of questionable utility as a teaching or thinking tool.

This approach is valid whether developing models to be used later in class, building models in a group environment with students, or directing student work. The progression of models from extremely simple to higher and higher complexity allows both modeler and user to fully understand the entire model. When this practice is included as part of the group development of a model of a system, the class interaction results in deeper understanding of the system. The progression allows model boundaries, levels of aggregation, leverage points and feedback loops to be understood by developing their functional importance step by step. They can be discussed as they come into play.

Each discipline in which models are used has topics which lend themselves to this approach. Consider a classic problem in thermodynamics which is often modeled:

> *You are given a cup of very hot coffee. You have to run a quick errand down the hall and will drink the coffee when you return in 10-15 minutes. You drink cream with your coffee. Should you add the cream now, or when you return? You want the coffee to be as hot as possible when you drink it.*

The temptation is to try immediately to build a model which includes all three types of heat flow, convection, conduction, and radiation. Doing so, however, actually can result in less understanding of the process than is really desirable. What makes the problem more complex is the fact that each of the rates affects how the other rates change. This is only clear if each heat flow is looked at separately. Building conduction, convection, and radiation models separately shows how much heat is lost in a given time period by each process. Combining all three processes in a single model (which, incidentally, almost always results in a simpler model than one built from scratch to show all three processes) reveals that the actual heat loss from each process is less than the single models show. This result is not intuitive or obvious for most students. The interrelationships of the system become more obvious. The understanding gained is greater.

Population models present a variety of options to explore increasing complexity. In particular, they provide an excellent example of a simplicityÕcomplexity progression that can be developed when starting with a system–focused problem that serves as a trigger for exploration of a complex system. Some global studies classes begin with a simple population model (figure 1) that shows incredible growth. The model can then be modified to look at land per person over time (figure 2) by the simple addition of converters. The graphs produced by this model usually generate more questions. These can be addressed by further modifying the model to include types of land (arable, forest, infrastructure, desert, etc.) or simply discussing these land types. Students may want to develop stock-flow diagrams to deal with transfer of land from one category to another. Either option leads to more detailed understanding of the role of land in population problems.

Similar patterns can be followed with food consumption and production. Again, whether through discussion of additional modeling or a simple population model with a few converters (figure 3), the system is explored in more depth.

Other pieces, as required, can be added to the model, while some may be removed. Teachers and students have included simple converters or stock–flow diagrams to represent immigration and emigration, industrialization, political and religious movements, shifts in cultural biases, shifts in diet, and other factors. The options are limited only by the time and effort allotted for exploration. Extremely complex and information–rich models can grow out of a very simple beginning.

The simple population model can also be a starting point for dealing with a very specific problem. A student participating in SyM*Bowl, a dynamic modeling competition for high school

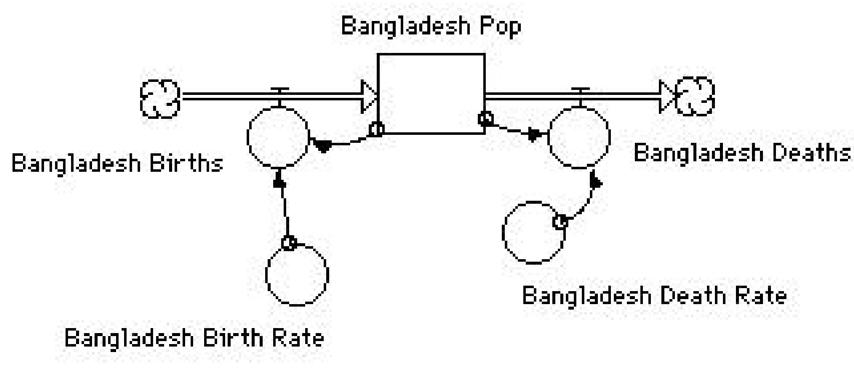

Figure 1

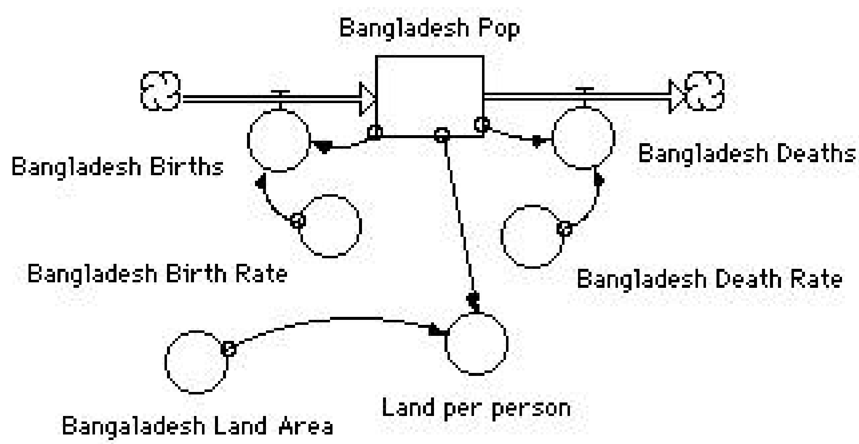

Figure 2

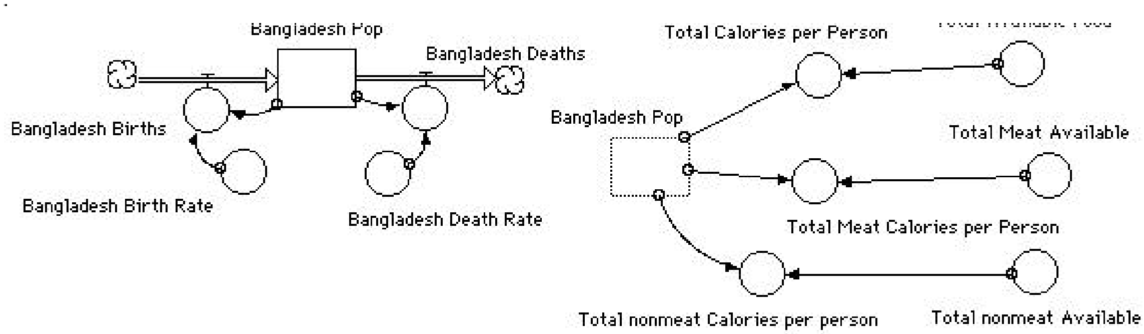

Figure 3

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students, chose to explore the impact of China's "One–Child per Family" population policy. Initially his work was designed to see if the policy was truly being implemented and whether or not it would be successful in controlling or reducing China's population. The simple model and a slightly more complex one tracking population by gender, revealed that culturally driven demographic shifts would have much more impact than the actual reductions in crude birth rate achieved by 1992 would imply. That required a significantly more complex model in which the male and female population models were broken into submodels based on population cohorts. The student's final model appears quite complex (one of the six sub-models is shown in figure 4). His work is an example both of the idea that complexity is best built from a simple start and that the "appropriate level of complexity," that is, the level demanded by the problem, can end up being quite high.

All content areas taught at the secondary levels have similar examples of problems and systems that can begin simply and have complexity added gradually. The process of moving from simplicity has an obvious cost—more time is needed to cover a problem or idea. The gain is greater comprehension of both the problem and the system. An additional gain is a gradually increasing understanding of the basic concepts of system dynamics, a goal that underlies all educational work with systems.

Emphasis on beginning with simplicity should not be construed as advocacy against complex models. They have their place, but that place is not as common as current practice might suggest. The purpose of using models in the classroom is to explore ideas, problems, and systems. The ability to generate numerical values sometimes blinds teachers to the fact that learning, when using models, occurs two ways. Model results answer questions and can pose new questions. However, the structure of well designed models can build an understanding of the model and the system they are designed to represent. Complex models frustrate this process. Simple models progressing to appropriate complexity facilitate the process.

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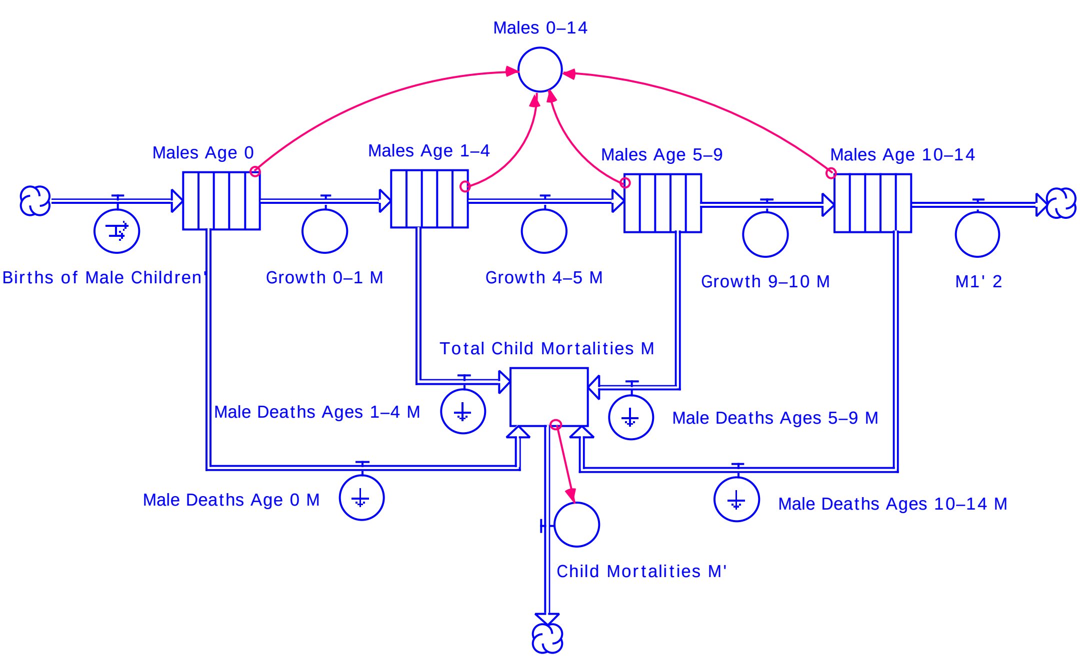

Figure 4

A Bachelor of Science Degree Program in System Dynamics at WPI

James K. Doyle, Michael J. Radzicki, and Khalid Saeed

Although system dynamics is currently taught in hundreds of schools at the K-12 level in the United States and in dozens of graduate schools throughout the world, there has historically never been a place where interested high school students could study system dynamics intensively at the undergraduate level. As a result, many students who excel in system dynamics in high school lose touch with the field when they go to college and miss out on the growing number of career opportunities in system dynamics. To address this problem, Worcester Polytechnic Institute, located in Worcester, Massachusetts, and known as the third oldest private university of engineering, science, and technology in the United States, has established the world's first bachelor of science degree program in system dynamics. The purpose of this article is to describe the design and implementation of the new program and its current status.

Undergraduate Education at WPI

The goals of WPI's system dynamics major are to train students to be critical thinkers, communicators, and leaders in business, society, and the world, as well as to equip them with the skills necessary to become system dynamics professionals in either public or private sector organizations. These goals are achieved through WPI's unique approach to undergraduate education, which emphasizes learner-directed learning, cooperative learning, and learning by doing. Every undergraduate student at WPI completes two extended research projects or "theses" in which they work in teams to solve complex, open-ended problems in close collaboration with faculty members. These research projects are often completed under the sponsorship of businesses or government agencies at one of WPI's many Project Centers in North America (in Washington, D.C. and Puerto Rico, for example) and throughout the world (in London, Venice, Bangkok, and many other cities). Consistent with WPI's educational philosophy, students in the B.S. program in system dynamics will learn the craft of system dynamics modeling by working with faculty in an "apprenticeship-style" learning environment.

The System Dynamics Major

In addition to using system dynamics to complete one or both of their research projects, students in the B.S. program in system dynamics will take a variety of courses designed to acquaint them with the "nuts and bolts" of SD modeling and related topics. The core of the program is a five-course sequence that introduces the system dynamics and systems thinking approach, covers both basic and advanced topics in system dynamics modeling and group model building, and culminates in a seminar in which students replicate and discuss classic system dynamics models and review the latest developments in the field. System dynamics students are also required to complete courses in basic science, computer science, and mathematics, in order to obtain an understanding of the scientific basis of system dynamics modeling, in addition to courses in social science, policy, and management that provide a background in the most popular fields to which system dynamics modeling has historically been applied. Finally, each student is required to complete a five-course sequence of applied courses in the area in which they choose to focus their modeling work. A dozen application areas are currently available, including economics, project management, public policy, environmental policy, computer science, and engineering systems. Students are also encouraged to develop and gain approval for new application areas that meet their particular interests.

The System Dynamics Minor

Students can also complete a minor in system dynamics at WPI by completing a sequence of six system dynamics courses. This option allows students to maintain their interest and build their skills in system dynamics while pursuing any of WPI's other successful major programs, including such options as computer science, electrical, chemical, civil, and industrial engineering, and biotechnology. Students may also, if they wish, obtain a double major at WPI, for example, in system dynamics and computer science.

Current Status of the Program

Implementation of WPI's B.S. program in system dynamics is well underway, with the first group of students declaring the major and taking advanced system dynamics courses in the 1998/99 academic year. In addition, in October of 1998 the program's advisory board, including such members as Jay Forrester, the founder of system dynamics, and Peter Senge, author of *The Fifth Discipline*, was established and met for the first time.

The program is now accepting applications from students who wish to begin the program in the Fall of 1999. Teachers and students who would like more information about WPI and/or the B.S. program in system dynamics may contact WPI's Admissions Office or Social Science and Policy Studies Department (which administers the system dynamics major) at:

WPI
100 Institute Road
Worcester, MA 01609-2280
(508) 831-5286 (Admissions)
(508) 831-5296 (SSPS)
admissions@wpi.edu
http://www.wpi.edu
http://www.wpi.edu/Academics/Depts/SSPS

Summary of the K-12 Listserve Question continued from page 2

clarity is ultimately expressed in language—how we share the model with others; and since our modeling does inform our understanding, therefore the language we use to speak of a system, of necessity, must be clear.

- What is the purpose of the model and who is the intended audience? This idea was mentioned in various forms by a number of people. Without these, as Ed Gallaher mentioned, there is simply no way to know boundaries and specifics.

- Reflecting on the meaning of the model will increase our ability to articulate assumptions and communicate new insights. This idea occurred often—to what extent do we ask our students to think about or defend the model they have created? Many mentioned that this should be occurring at the earliest time and continue throughout, increasing in complexity as students build felicity with their explanations.

- We ought to develop and practice dialog skills needed when talking about systems. Use a "Learning Journal" … ah-hah's, puzzlements, questions, how does today's learning apply to tomorrow's responsibility, how can we increase learning in future sessions? Some of us recently met in Portland and discussed journals, students maintaining an intellectual record of their learning and thinking. It is a VERY successful piece in a student's intellectual journey.

- Naming stocks and flows is a significant issue—vocabulary in relation to stock—being able to talk through the story illuminates stocks and flows for students

- Clear Diagrams. Self-evident variable names. Careful layout. Smoothly curving connectors. No spaghetti. If you show your model to another student, he or she should be able to immediately describe what the model is attempting to illustrate.

VARIETY

- Early on, students should see the multiplicity of systems in their lives, that systems do not apply only to science or only to mathematics. Even though there is variety, there is also pattern, what one participant called "archetypal subsystems." This can be accomplished by working with LOTS of different examples of simple systems to more complex systems through large/small group discussion.

- We should tell stories—very short stories. Allow students to write, to use their own language to piece together a whole story. Language is well suited to describe systems after all. One need only read Tolstoy or Dickens or Atwood to experience this.

- Use manual graphic techniques … that provide verbal/mathematical models. Graphic techniques are easy to grasp and leave little room for misunderstanding, provided one is rigorous in defining terms and use of different elements.

TWIXT STOCKS AND FLOWS

- Deciphering: if we look at the system in an instant in time, i.e., stop time, what do we have? Stocks have finite amounts … and, more importantly, their units are not given in terms of time.

- A stock is noun/subject of the story; the flow is the verb/action that is taking place.

- Context helps reconcile STOCK and FLOW; the boundaries and time course are also part of one's knowing the difference.

ON HABITS OF THOUGHT

- Translating from a written problem to a stock and knowing the connections among parts within the system—this compiled from a study within Maryland—these correlate with success in a systems class. Further, recognizing patterns and relating two sets of data are qualities of mind necessary for success. This data suggests broad mental capacities we ought to engender in our youngest students.

Call for Papers

1999 International System Dynamics Conference
Systems Thinking for the Next Millennium
20-23 July, Wellington, New Zealand

Submissions for plenary sessions, parrallel sessions, tutorial sessions and workshops are invited. One-page abstracts should be sent to the Programme Chair by 1 February, 1999.

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REALITY

• Convincing students that dynamic modeling can aid them in understanding complex situations and arriving at solutions to vexing problems

• Students need to recognize behavior as it unfolds in the real world and identify model structures that generate the same behavior. -Jay Forrester

QUOTABLES

• "The more examples the better from several different disciplines, analysis of local problems, analysis of newspaper articles that represent systemic problems, analysis of problems or simple systems familiar to the students in their daily lives." Teresa Hazel

• "My guess is there are some obvious stocks and flows that nobody has trouble with and some others that raise interesting questions." George Richardson

• "It is important to get across the idea that SD is not just a program that adds up little bits and pieces (which it does), but that it was developed to facilitate the study of feedback systems … Until we start looking at (and understanding) feedback processes we might as well be using a spreadsheet." Ed Gallaher

• "Students must be comfortable sharing their individual assumptions about the system (perhaps by diagramming or graphing) and allowing their peers to review/critique/enhance those assumptions … written/oral communication allows the students to internalize and share insights gained through their work with the dynamic model." Will Glass-Husain

• "All activity everywhere occurs within and is controlled by feedback systems."

• "Realize that models are a part of thinking." Jay Forrester

• "Perhaps we should expand "students" to include educators as we learn the concepts of systems. Are we not teaching ourselves?" Eileen Riley

Compiled by Tim Joy

Ode to Joy

"Alle Menschen …" —oops, that Ode to Joy has already been written (by Ludwig somebody or other), and besides the next word contains an umlaut which just doesn't come across well in text-based email servers.

I want to thank Timothy Joy for his summary of the monthly question.

In clarity of thought there is poetry.

So, although you claim not to have Robert Frost in your mind, you have certainly put poetry in mine. I appreciate the care and thoughtfulness, and poetry, with which you summarized last months' dialogue. It was a welcome gift.

John W. Gunkler
<jgunkler@sprintmail.com>

K-12 Listserve

The summary article is from a monitored list for discussion of system dynamics in K-12 education. For past discussions see: http://sysdyn.mit.edu/k-12sd-email-list/archive/home.html Send contributions and all requests to subscribe and unsubscribe to: k-12sd@sysdyn.mit.edu

The Panasonic Foundation

The Panasonic Foundation was established in 1984 with an endowment from the Matsushita Electric Corporation of America, and is dedicated to the improvement of public elementary and secondary education in the United States. Its mission is to help public school systems that serve high percentages of children in poverty to improve learning for all children so that they may use their minds well and become productive, responsible citizens.

Believing that all children can learn and that all students can achieve higher levels of learning than they currently are achieving, the foundation works with public school districts and their schools to redesign their education systems. They do this by providing direct technical assistance through the Panasonic Partnership Program, which establishes five- to ten-year partnerships with the districts.

The foundation works with a core group of about 20 senior consultants who provide ongoing technical assistance to the partner school systems. The prospective partner district must serve large numbers of disadvantaged youth. In addition, they look for districts that exhibit agreement with the foundation's underlying and operational beliefs about systemic, school-based, whole-school reform and a commitment to develop a serious restructuring agenda, including allocation of time and resources.

Districts interested in exploring a partnership with the foundation are invited to write for more information.

Panasonic Foundation
2 Panasonic Way, 7G7-A
Secaucus, NJ 07094
Phone 201-392-4132
Fax: 201-392-4126
info@foundation.panasonic.com

Newsletter Subscription Information

The Creative Learning Exchange Newsletter is available in three different formats:

- On the web page at http://sysdyn.mit.edu/cle/
- As an attached file to an e-mail
- In paper via US mail ($15.00 outside the USA)

Since we vastly prefer electronic distribution to paper because it so much less expensive, please e-mail us at any time when you would like to have an electronic subscription.

<milleras@cle.tiac.net>

Gordon Stanley Brown Fund

To support preparation for distribution of
materials for using system dynamics in K through 12 education

The Gordon Stanley Brown Fund has been established to promote system dynamics and an understanding of dynamic behavior in feedback systems in kindergarten through 12th grade schools. The Fund will focus on making teaching experiences available to others. Small and medium sized proposals are encouraged.

The Gordon Brown Fund can support teachers for:

- Released time or summer time used to put into transmittable and usable form materials and methods that have already been used in schools and that could be of help to others,
- Communicating experiences that did not meet expectations so that others can be forewarned.

Work supported by the Fund is to be available for distribution through the Creative Learning Exchange and any other channels that the author arranges.

The Fund honors Gordon Brown, who pioneered the theory and practice of feedback dynamics and engineering control systems at MIT in the 1940s. Brown went on to be head of the Electrical Engineering Department and Dean of Engineering at MIT. During retirement, he devoted energy and skillful leadership to bringing system dynamics into the Catalina Foothills school system in Tucson, Arizona.

Address applications, with an outline of the proposed project, to:
Lees N. Stuntz, Creative Learning Exchange, 1 Keefe Road, Acton, MA 01720

INTERESTED IN INVESTING?

If you would like to invest in our effort here at *The Creative Learning Exchange*, your contribution would be appreciated. You may donate any amount you wish; perhaps $50.00 is a reasonable amount for a year. All contributions are tax-deductible.

Enclosed is _________________ to *The Creative Learning Exchange* to help invest in the future of K-12 systems education.

Name ____

Address____

____

e-mail ____

Thank you!

***The Creative Learning Exchange*, 1 Keefe Road, Acton, MA 01720**

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