Value of Model-Based Simulators for Teaching Systems Thinking Principles and Dynamic Content

Gary B. Hirsch
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Overview

• Why simulators?

• Examples
  – Physics: Driving/Home Energy/Sports
  – Economics: Newspaper/Retail Store
  – Management--School Reform

• Discussion--How can simulators best enhance the curriculum? Where do they offer the greatest advantage?
Why Simulators?

- Developing models is an excellent way to learn ST/SD
- But it may create a barrier for teachers and students who have not yet developed modeling skills
- Packaged simulators can help teachers and students develop intuition about dynamic systems and content
- Thereby creating a larger potential audience for Systems Thinking and System Dynamics
Advantages of Simulators

• Present models and results in more familiar format with a lot of support; can control level of detail and different degrees of transparency

• Can integrate models with other curricula; delivered in just-in-time fashion as needed

• Support scaffolded inquiry and self-directed learning; serve as laboratories for genuine exploration
Physics Simulators
Background on Physics Simulators

- Developed in conjunction with Vermont Institute of Science, Mathematics, and Technology (VISMT) and physics teacher Jim Jones; NSF funding

- Created as a companion to the Active Physics curricum

- Purpose of simulators was to give students a way of relating lessons back to real-world experience
Use of Simulators with Active Physics Curriculum

1. Exploration of Concepts via Laboratory Experiments
2. Elicitation of Ideas Based on Experience
3. Students' Real World Experience
4. Understanding of Concepts in Context of Real World Experience
5. Exploration of Concepts Through Simulation of Real-World Situation
Travel Around a Curve as a Dynamic Phenomenon

- Net Radial Acceleration
  - Centripetal Acceleration Required
  - Radius of Road
  - Forward Velocity
  - Initial Velocity Going Into Turn

- Centripetal Acceleration Due to Friction
  - Driver Reaction
  - Road Surface
  - Initial Velocity Going Into Turn

- Banking Effect
  - Real Radius of Turn
Travel Around a Curve

Get Around the Curve Safely!

**Radius of Curve**
- 50 Meters (164 Feet)
- 100 Meters (328 Feet)
- 150 Meters (492 Feet)
- 200 Meters (656 Feet)

**Surface Quality**
- Dry
- Slick
- Icy

**Velocity Around Curve (m/s)**
- 0 Miles per Hour
- 10 Meters per Second

**Angle of Banking (Degrees)**
- 0 Degrees
- 30 Degrees

**VELOCITY**

Pick a radius of the curve, starting with 100 meters or less, and keep it constant for this set of simulations. Don't change anything else for now. Do several simulations using different velocities, some low and some high. As you see which ones send the car off the road, try to find the velocity that is the point at which the car will go into a skid. Now double the radius. Can you double the speed and still stay on the curve? Why or why not? For each run, see how the trajectory (path the car takes) relates to the graphs for Radial Acceleration, Velocity, etc.
Travel Around a Curve

Get Around the Curve Safely!

Position vs. Road

- Coordinate of Road: Road100
- Coordinate of Actual Trajectory: t100x40

Centripetal Acceleration Required

- Centripetal Acceleration Required: r100x40
- Actual Radius of Turn: r100x40

Do Analysis  Tutorial  Set Up a New Run
Travel Around a Curve

Get Around the Curve Safely—Tutorial

Why does steering back toward the road make things worse? The diagram at the left will give you a hint. If you enter a curve too fast, the car will begin to skid off the road and move in a Trajectory with a larger Radius. This will go on until equilibrium is reached—the Radius of the Trajectory becomes large enough for the Forward Velocity and Friction can hold the car in this larger Trajectory.

Steering back toward the road has the opposite effect. As you can see on the diagram, that turn has a very small Radius, much smaller than the equilibrium Radius and also smaller than that of the Road itself. The small Radius of this turn creates a larger Centripetal Acceleration Required that, in turn, makes the car harder to control. This turn can cause the car to swing in a wider arc.
Collisions

What Happens When You Collide?

Your Vehicle
Type: Sedan
Speed: 20

Other Vehicle
Type of Vehicle:
- Sports Car
- Sedan
- SUV
- Truck

Direction of Travel for Other Vehicle

Experiments

Go to Simulation
Go Back to First Setup

Do Analysis
Back to Intro
Exit
# Heat Flow/Energy Conservation

## Find the Money Hidden in Your House!

<table>
<thead>
<tr>
<th>Month</th>
<th>Latitude</th>
<th>Square Feet</th>
<th>Stories</th>
<th>Quality of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>1,500</td>
<td>1</td>
<td>Drafty</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td></td>
<td>2</td>
<td>1960's Average</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td></td>
<td>3</td>
<td>Better</td>
</tr>
</tbody>
</table>

- **Provide Heating and Cooling?**
  - No
  - Yes

- **Set Heating and Cooling Capacity (BTUs per Hour)**
  - Heating: 0
  - Cooling: 0

- **Thermostat Setting**
  - Heating: 50
  - Cooling: 68

## Experiments

- Insulation
- Overhang/Shading
- Solar Heat
- Efficiency
- Design Problems

[Back to Intro]
[Exit]
Heat Flow/Energy Conservation

Find the Money Hidden in Your House!

Cumulative BTUs Supplied or Removed

Total BTUs Supplied by Heating and Cooling in a Day: 40K insult
Total BTUs Supplied by Heating and Cooling in a Day: 80K heat
Total BTUs Supplied by Heating and Cooling in a Day: 40K heat

Conduction
Infiltration
Solar Gain
Supplied
Temperature
Total BTUs
Load/Unload
# Heat Flow/Energy Conservation

## Find the Money Hidden in Your House!

<table>
<thead>
<tr>
<th></th>
<th>40K insul</th>
<th>80K heat</th>
<th>40K heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Heating BTUs</td>
<td>535,000</td>
<td>1.48 M</td>
<td>895,000</td>
</tr>
<tr>
<td>BTUs/HDD/Sq. Ft.</td>
<td>8.773</td>
<td>24.26</td>
<td>14.67</td>
</tr>
<tr>
<td>Daily Heating Cost</td>
<td>7.031</td>
<td>19.45</td>
<td>11.76</td>
</tr>
<tr>
<td>Annual Heating Cost</td>
<td>972.08</td>
<td>2,539</td>
<td>1,626</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total Cooling BTUs</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BTUs/CDD/Sq. Ft.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Daily Cooling Cost</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Annual Cooling Cost</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>964.31</td>
<td>0</td>
<td>0</td>
</tr>
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</table>

*See the "Payback" Tutorial for More Info. on Using This Data*
Pole-Vaulting

Now that you've studied the effects of each of these variables individually, you can now try a combination that you haven't tried yet.

Really good pole vaulters can jump even higher than their running speed would indicate because they can apply extra force in three other places. Use the check boxes at the left to see the effects one or both of these as well.
Pole-Vaulting

Height of Jump and Potential Energy Stored

Height Reached by Vaulter (Meters)

Energy in Height of Vaulter (Joules)

Select Simulations for Graphing  Previuos  Main Results Graphs

Do Another Experiment  Try Pole Vaulting on the Moon  Exit
Economics Simulators/Simulation Games
Additive Value and Desirable Properties of Games

• More engaging, leads to greater cognitive impact
• Encourages active learning in pursuit of a goal
• Designed for an intended audience and specific learning objectives
• Provide agency
• Allow for multiple levels of play
• Strong psychological dimensions
• Meaningful choices, possibly under time pressure
• Ability for players to get better with experience
• Conceptual tools that let the player understand the dynamic nature of game and real-world situation
• Emergent properties that are hard to predict
Newspaper Simulator--Overview

Run Your Own Newspaper Simulation Game --

- Prices and Revenues
  - Number of Subscribers
    - News Content and Quality
      - Number and Kinds of Staff
        - Bank Balance, Profits, and Dividends
          - Bank Balance Graphs
            - Subscriber Graphs
              - Revenue Graphs
                - Advertising Graphs

- Advertising
  - Advertising Graphs
  - Content Graphs
    - Cost Graphs
      - Cost

Go To: Decisions, Results, Testing, Introduction
Newspaper Decisions

Decisions

- Hiring:
  - 0.0
  - 5.0

- Firing:
  - 0.0
  - 2.0

- Subscription price:
  - 0
  - 52

- Bank balance:
  - 420,203

- Subscribers:
  - 86

- Total staff:
  - 2

- Ad column inches:
  - 3

- Percent staff editors:
  - 0%
  - 33%

- Percent staff reporters:
  - 0%
  - 33%

- Percent staff sales reps:
  - 0%
  - 33%

- Allocated:
  - 100

- Unallocated:
  - 0

- Run
- Stop

- Overview
- Decisions
- Results
- Info on Testing
- Time Interval
Modern Electronics:
Teaching Economics to High School Students with a
System Dynamics Simulator
Goals of the *Modern Electronics* Simulator

• Make Economics Less Abstract by Relating It to a Familiar Setting

• Introduce ST/SD Concepts, Especially Interrelationships Among Parts of a System

• Use Simulation as an Opportunity for Experiential Learning--Do Experiments, Construct Understanding

• Expand on Simple Economic Concepts
  – Decisions Are Multifaceted
  – Selling is a Complex Process
  – Availability, Selection Can Be as Important as Price
Design Principles

• Provide Overview to See Whole System at a Glance

• Create Ability to Drill Down, Get Into More Detail in Specific Areas

• Closely Relate Structure and Behavior

• Provide Information in Multiple Formats to Support Different Learning Styles

• Support Iterative Learning by Comparing Results
Modern Electronics: Business Basics

- Consumer Electronics
- Average Price = $100
- Medium Range of Merchandise (Variety)
- 3 Staff
- Start with $200,000 in the Bank and $50,000 in Inventory
How to Play the Modern Electronics Simulation Game

**Four Things Attract Customers to Your Store...**

- **Service Quality**
- **Prices**
- **New Customers' Advertising**
- **Range of Merchandise**

**ATTRACTING CUSTOMERS TO YOUR STORE**

Running a successful store requires you to attract and keep as many customers as possible. The diagram at the left shows that four things will affect how many new customers you attract.

**SERVICE QUALITY:** Do you have enough staff? Do they wait on customers quickly? Are they knowledgeable about the products? In this game, we assume that Service Quality will depend on the number of customer visits each staff person has to handle. If staff are too busy, they cannot provide good service! You will have the opportunity to hire and fire staff and affect Service Quality (see the next screen).

**PRICE:** Are your prices competitive with other stores that sell the same kind of merchandise you do? Are the products you sell a good value for consumers? While there are many different prices on the items in a store, you will control the average price. You start with an average...
Providing Quality Service Means Having Quality Staff...
Customer Visits and Product Availability Create the Revenues Your Store Needs to Succeed...
Expenses Get Subtracted from Revenues...You're Left with the Cash to Run the Store
Graph for Regular Customers

Regular Customers: low price
Regular Customers: base

Time (Weeks)
### Quarterly Profit and Loss Statement for Modern Electronics Corp.; Weeks 39 to 52

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Revenues</td>
<td>$5,998</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
<td>3,747</td>
</tr>
<tr>
<td>Gross Profit</td>
<td>2,250</td>
</tr>
<tr>
<td>Selling Expenses</td>
<td></td>
</tr>
<tr>
<td>Salaries</td>
<td>24,871</td>
</tr>
<tr>
<td>Rent</td>
<td>15,071</td>
</tr>
<tr>
<td>Advertising</td>
<td>13,000</td>
</tr>
<tr>
<td>Overhead</td>
<td>26,000</td>
</tr>
<tr>
<td>Total Expenses</td>
<td>78,943</td>
</tr>
<tr>
<td>Net Income (or Loss-)</td>
<td>-$76,692</td>
</tr>
<tr>
<td>Before Taxes</td>
<td></td>
</tr>
</tbody>
</table>

### Management Report for Modern Electronics Weeks 39 to 52

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Sales</td>
<td>74.98</td>
</tr>
<tr>
<td>Cost per Unit</td>
<td>$49.98</td>
</tr>
<tr>
<td>Cost per Unit Sold (Including Selling Expenses)</td>
<td>$947.26</td>
</tr>
<tr>
<td>Staff</td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>2.450</td>
</tr>
<tr>
<td>Trainees</td>
<td>0.0689</td>
</tr>
<tr>
<td>Regular Customers</td>
<td>514.06</td>
</tr>
<tr>
<td>New Customers</td>
<td>385.30</td>
</tr>
<tr>
<td>Inventory (Units)</td>
<td>119.57</td>
</tr>
<tr>
<td>Space Utilized (Square Feet)</td>
<td>2,511</td>
</tr>
<tr>
<td>Cash in the Bank</td>
<td>-$59,363</td>
</tr>
<tr>
<td>Value of Inventory</td>
<td>$5,976</td>
</tr>
</tbody>
</table>
School Reform Simulator
Anchor River School District--Introduction

- Suburban district with
  - 2500 students
  - 250 staff
  - $12.5 Million budget

- Stable history, but mandated statewide testing has been implemented

- Vouchers have been proposed to make education more “competitive”
Overview

Change and the Anchor River Public Schools--Will School Reform Get in the Way of Reforming Education?

Activities Affecting Innovation

Curriculum Innovation and its Impact

Budget and Staff Time Available

Students Ability to Learn

Staff Time per Student

Students in Alternative Schools

Student Enrollment and Problems

Trust Between School and Community

School Performance
Stable Outcome Without School Reform
Results of Imposing Stringent Standards and High-Stakes Testing
Reinforcing Loops That Exacerbate Problems Caused by External Standards
Effect on Enrollment of Alternative Schools (Vouchers)
Effect on Performance of Alternative Schools
Strategies/Scenarios to Try--
One at a Time and in Combination

- Add or eliminate traditional curriculum
- Do more professional development for teachers
- Devote a higher (or lower) fraction of staff effort to remedial help
- Implement new curriculum
- Change mode of student evaluation, structural flexibility
- Assume higher initial budget or level of trust
- Examine effects of instituting a voucher system
Reinforcing Loops Affecting Curriculum Innovation

- Teacher Motivation
- Curriculum Innovations Adopted
- Staff Time Available
- Structural Flexibility
- Other Demands on Teachers
- Measured Impact of Innovation
- Budget Available
- Trust of Community in Schools
- Students Ability to Learn
- Performance on Traditional Curriculum
- Methods of Student Evaluation
Curriculum Innovation--Making Things Worse
Results with Curriculum Innovation and Modest Cutback in Traditional Curriculum
Discussion

• How can simulators best be used to enhance curriculum?

• How can simulators be used to promote interest in ST/SD?

• What are promising curriculum areas for introduction of simulators?

• How can simulators be used to help improve management of schools?
For more information, complete papers, and downloadable simulators, go to:

www.GaryBHirsch.com