the Creative Learning EXCHANGE

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The Tree Game: *The Shape of Change*

Text of Lesson 6: "The Tree Game" from the book ***The Shape of Change***
by Rob Quaden and Alan Ticotsky with Debra Lyneis. Prepared with the support of
The Gordon Stanley Brown Fund. Based on work supported by **The Waters Foundation**

Introduction

Students explore what happens to the number of trees in a forest over time as a forester plants and harvests a certain number of trees each year. Playing the game, students experience resource management and the need for long term planning. The Tree Game complements science, social studies, economics and ecology units on renewable resources and sustainability. Math skills include computation, graphing from tables, and understanding the causes of patterns of change over time.

How It Works

Students play a game that simulates the growing and harvesting of trees. The game is set up so that the company's stock of trees increases at a constant rate: the forester plants the same number of new trees each year. However, the trees are harvested at an increasing rate: the forester doubles his cutting rate each year. In addition to giving students an intuitive understanding of linear and exponential change, the game illustrates the difficulties of supplying a natural resource product in an environment with rapidly growing demand.

Materials Needed

- Approximately 150 wooden craft sticks (Popsicle® sticks) for each team of students
- One container for each team to hold the sticks
- One copy of two worksheets for each student: (samples only in this article)
  1. *Forest Inventory Table*
  2. *Forest Inventory Graph*

Procedure

1. Ask each team of 3 or 4 students to count 120 sticks into their container. The remaining sticks should be put aside in a neat pile on the table.

*This is a **simulation**. Since we have neither the time nor the resources to experiment on a real forest, we use sticks to play out our forest management policies in class.*

2. Explain to the class that the container of sticks represents a forest which will undergo some changes.
   - Each year trees will be added and removed according to a certain rules.
   - The sticks that are added represent new trees planted; the sticks that are removed represent trees that are cut down to provide lumber for housing, production of paper, etc.

3. Explain that each person on the team will have a job. Post the job descriptions on the board for quick reference.
   - The Forest Managers will plant new trees each year. (The manager starts with a small pile of sticks to add in.)
   - Lumberjacks will cut trees down each year. (They will remove sticks.)
   - Record Keepers will keep track of the inventory data in a table.

***The Tree Game** continued on page 3*

THIS ISSUE AT A GLANCE

Updates…

Glynn County Schools

Steve Kipp reports that the training program which they instituted this summer was particularly successful, in part because it was based on the *Habits of a Systems Thinker* (adapted by Mary Scheetz from Linda Booth Sweeney's "Ways of a Systems Thinker"). The training emphasized teacher collaboration, and they have concentrated on consistent observational follow through with the teachers who came to the training. Systems training remains an integral part of their professional development program under the auspices of Margie Varnado. The program allows them to reach administrators, teachers, and community members with the concepts and tools of systems thinking.

Steve is especially excited to be going to India this month for two weeks to help an Indian school—the Rewachand Bhojwani Academy—get started with systems thinking and dynamic modeling. He came in contact with a businessman friend of the school administrator through a Waters Foundation training in Virginia this summer.

EDITORIAL

Here in New England the leaves have finally lost their grip on the trees. Our first snowstorm covered the ground with about four inches of snow, so the landscape looks as if cold winter weather is upon us, with the holidays approaching quickly.

We at the CLE are concentrating on moving our office across town. We find that a major cleanout after 13 years of residence is a lot of work and a great idea!! Over the 13 years that the CLE has been in existence, we have gone from entirely paper based (anyone interested in several hundred plastic in-boxes?) to 99% web and CD based. We are recycling a lot of paper these days. Our move should be complete by December 1. Make sure to note our new address and telephone numbers. See below. Email addresses will remain the same.

We would love to hear from you about what is going on in your classrooms and how you are teaching your students to think more deeply and critically by utilizing systems tools and concepts.

Have a peace-filled holiday season, enjoying your family and friends.

Take care,
Lees (Lees Stuntz, *stuntzln@clexchange.org*)

New Address and Telephone Numbers

The Creative Learning Exchange has a new address and telephone numbers, effective December 1, 2004. We can now be reached at

The Creative Learning Exchange
27 Central Street
Acton, MA 01720

Telephone 978-635-9797 Fax 978-635-3737

Please correct your address books to reflect these changes. Thank you.

Call for Papers

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The Tree Game*, continued from page 1*

4. Explain the rules of the game to students.
   - You start with a forest of 120 trees.
   - Each year plant 4 new trees.
   - The first year, cut 1 tree. This represents the wood that is used for building houses, making paper etc.
   - The second year, cut 2 trees; the third year, cut 4 trees, and so on. In other words, the number of trees you remove from the forest *doubles each year*.
   - Each year, the managers add sticks, the lumberjacks take away sticks, and the record keepers record the data on the *Forest Inventory Table*.
   - Be as accurate as possible.

5. Students record their data on the *Forest Inventory Table* (page 8 of the actual lesson). Although data is collected in teams, each student completes an individual worksheet. Point out that part of the table has already been filled in on the worksheet. Ask students to play the first round (the first year) to confirm the results.

   Starting with 120 trees, students plant 4 trees and cut 1, leaving them with 123 trees to begin Year 2, as shown below.

Year	**Number of Trees in the Forest**	**Number of Trees Planted**	**Number of Trees Cut Down**
Start	120	4	1
1	123		

6. Teams then continue to play and record their results. Help any teams that need clarification. Here is a completed table.

Year	**Number of Trees in the Forest**	**Number of Trees Planted**	**Number of Trees Cut Down**
Start	120	4	1
1	123	*4*	*2*
2	*125*	*4*	*4*
3	*125*	*4*	*8*
4	*121*	*4*	*16*
5	*105*	*4*	*32*
6	*77*	*4*	*64*
7	*17*	*4*	*Not enough left*

Note: Often students will start to see patterns and fill in the table based on that pattern, rather than actually counting sticks. Depending on the age of the students, it helps their understanding if they can force themselves to keep using the sticks for a while.

***The Tree Game** continued on page 4*

The Tree Game, *continued from page 3*

8. By Round 7 of the game, students will report that they have no trees left.

? **Why did students run out of trees to cut?**
The increasing demand outstripped the supply. There were not enough trees left to cut in Year 7. The forest is gone.

9. Ask each student to use the data from the *Forest Inventory Table* to plot the *Forest Inventory Graph* (A blank graph is included on page 9 in the lesson). Students connect the points with a smooth line to show what happened to the stock of trees over time.

Bringing the Lesson Home

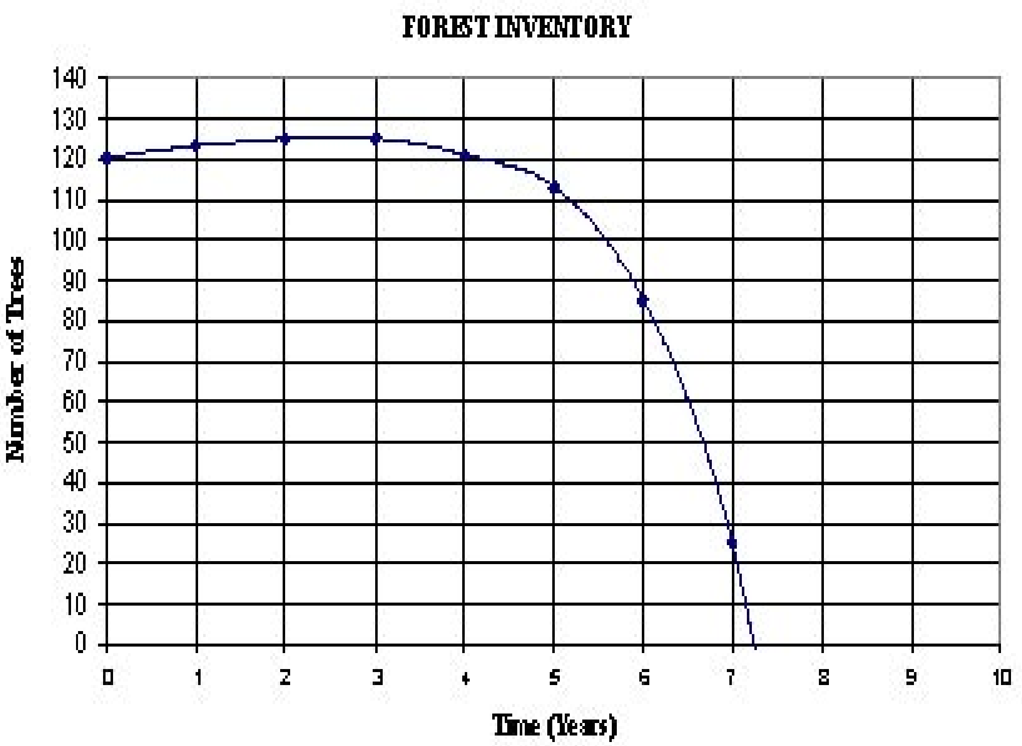
Post several student graphs and use them to focus the discussion on what happened in the game. The following questions should arise, often raised by the students themselves.

? **How does the graph show what happened to the stock of trees in the forest over time?**
The stock of trees grew slightly at first but then rapidly decreased until there were no trees left by the seventh year.

? **When did the forest grow? Why?**
The forest grew for the first two years because students were planting more trees than they were cutting down each year.

? **When did the forest decline? Why?**
The forest began to decline in the fourth year because students were cutting down more trees than they were planting each year.

? **Did the forest ever stay the same? Why?**
The forest stayed at 125 for Year 3 because students planted 4 trees and cut 4 trees. There was no change in the total number of trees that year.



What happened to the forest?
Students use line graphs to reveal and examine patterns of change.
We call these *behavior over time graphs*.

? **Why did the forest grow in size for a while and then start to decline?**
At first the planting rate exceeded the cutting rate so the forest grew. However, because the cutting rate doubled each year, it soon overtook the planting rate. Then the forest declined.

? **Why did the rate of decline increase as time went on?**
The number of trees cut doubled every year to meet the rising demand for lumber. As more and more trees were cut, the decline steepened.

? **What caused the changes in the stock of trees?**
The total number of trees in the forest

The Tree Game *continued on page 7*

Does a Model Facilitate Learning?

Some preliminary experimental findings

by David Wheat, Larry Weathers and Robin Goldstein[1]

The purpose of the experiment described in this paper is to compare the learning that takes place with different methods of delivering essentially the same information about Gross Domestic Product to student groups. The main delivery methods discussed are (1) simple narrative only, and (2) the same narrative, accompanied by a diagram revealed in stages, using STELLA's "story" feature. This experiment was administered to secondary students in the Harvard Public Schools in Massachusetts, and to community college and secondary students in Virginia. Tentative results suggest that students having access to the model structure learn more than students receiving only narrative instruction.

1. The Problem

Economics instruction is under a microscope, and the picture is cloudy. Experiments by economists suggest that the value added by economics courses is "minimal" (Walstad and Allgood, 1999), economics literacy rates are only "modestly" encouraging (Wood and Doyle, 2002), and comparative statics instructional methods may be no more effective than mere verbal instruction (Cohn et al., 2001). Students often find it difficult to see how the proliferating textbook graphs relate to one another, and how the variables on different graphs interact to influence economic system performance. The elusive dynamics of interaction is almost certainly missed by students just struggling to keep track of the *ceteris paribus* assumptions behind each new graph. Heavy reliance on "chalk-and-talk" lecture methods (Becker and Watts, 1998) may compound the problem. What could explain the apparent weakness in economics instructional methods, and what solution is available?

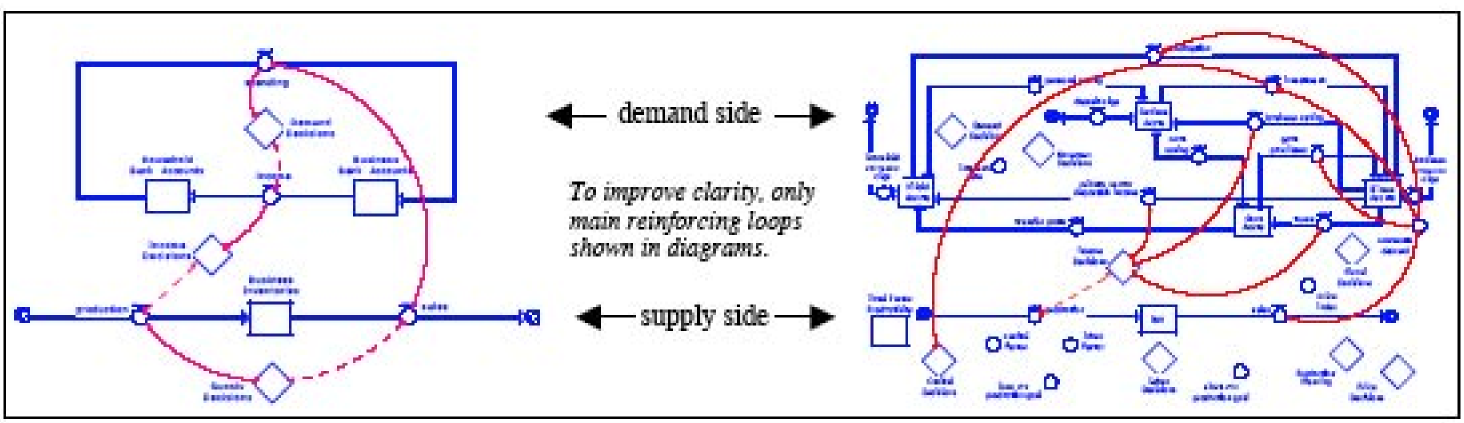
Our hypothesis is that the traditional macroeconomics instructional method—graphical comparative statics presented in a lecture format—provides a weakly structured learning pattern for most economics students. Over forty years ago, educational psychologist Jerome Bruner (1963) concluded that "…the most basic thing that can be said about human memory…is that unless detail is placed into a structured pattern, it is rapidly forgotten." Brunerr's *structured pattern* is Jay W. Forrester's (1994) system dynamics "…*framework* into which facts can be placed [so that] learning becomes more relevant and meaningful."

We share Forrester's vision. Two of the authors are actively engaged in implementing systems thinking and system dynamics modeling in a Massachusetts public school. The third is developing and using a system dynamics model and interactive learning environment (ILE) in a macroeconomics distance-learning course at a community college in Virginia. Also under development is a set of experiments to test the effectiveness of that ILE as an instructional tool. One of those experiments is the subject of this paper.

2. *MacroLab*

The ILE is called *MacroLab*, and it consists of six major learning units designed for a one-semester course in introductory macroeconomics (Circular Flow, Supply Side, Demand Side, Government, Money & Banking, and Exports & Imports).

Underlying System Dynamics Model. The model, built with STELLA[2] software, makes use of a traditional macroeconomics concept—a circular flow of income and spending—recast in stock and flow terms as the nominal "demand side" of an economic system. The "supply side" features a classic system dynamics representation of aggregate flows of real goods and services—production and sales—buffered by an inventory stock. Sales trends and inventory conditions provide information feedback that affects production goals and employment of factors of production. With real sales driven by nominal spending, and with nominal income driven by real production, the loop is closed between the demand and supply sides.



Starter Model (left) in Week 2 Figure 1. End-of-course Model (right)

Model continued on page 8

DynamiQUE*ST* 2005

March 4th, 9am—3pm

Campus Center, Worcester Polytechnic Institute, Worcester, MA

Come join us for the sixth annual DynamiQUE*ST*!

The what and why…

*Students (and teachers) are at various places along the road to developing proficiency with thinking systemically and employing System Dynamics/Systems Thinking (SD/ST) to address complex issues and increase understanding. We seek to encourage students and teachers to develop an understanding of the use of SD/ST tools. We also know that we need an environment, free from the "winner/loser" constraint, where kids can receive feedback from other kids as well as from teachers and professionals well versed in SD/ST. DynamiQUE**ST** creates a venue for both celebrating what has been done and providing encouragement for all to continue!*

In this spirit, DynamiQUE***ST*** was launched in 2000. DynamiQUE***ST*** 2005 will provide a venue for students in Grades 3-12 to showcase work in which they have employed the tools and method of system dynamics. This effort has several purposes:

- Provide a way for students to meet other students and see what they are doing
- Permit teachers from different schools to see evidence of student work in ST/SD
- Provide a venue for teachers and kids to network
- Have some fun and celebrate with your kids!

The how…

Simple! Have a place where students from around the country can bring their SD/ST work for others to see. Don't pit kids against each other, but hold their work accountable to a set of clearly defined standards (see DynamiQUE***ST*** 2005 Rubrics). Give them (and their teachers) a chance to see "where they are" and "where they can go from here."

But, but…

"My kids are at different stages in learning and understanding the tools and method of SD/ST. Why would we make the trip just to bring our BOTG's?"

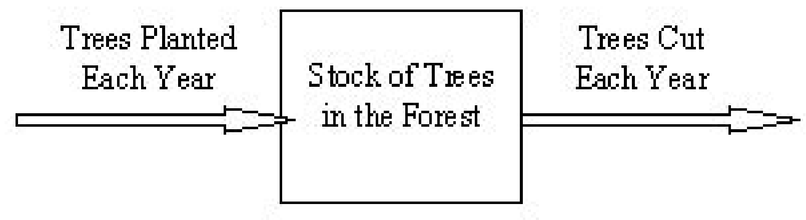
Of course they are, and this is precisely why you should make the trip! The use of standards allows kids to see their work as a point in time along a learning continuum and see where they can go next. DynamiQUE***ST*** 2005 provides rubrics for any combination of SD/ST tools from a simple (but powerful) BOTG to a full-blown, dynamic model. The 5th grader's BOTG is as valid as the 11th grader's functional model! Both represent vital stages in the development of a systems thinker/dynamic modeler. Let's take some time to see this work, have kids see each other's work, and celebrate where we are and where we are going.

What now…

Look over the guidelines provided on the CLE website. Begin to plan, with your students, what you will bring to DynamiQUE***ST*** 2005!

The Tree Game, *continued from page 4*

was determined by BOTH the planting and the cutting of trees over time. This is an important concept.



There is a **stock**, or quantity, of trees in the forest. It is increased by the number of new trees that **flow in** through planting. It is decreased by the number of trees that **flow out** through harvesting. Like water filling and draining a bathtub at the same time, they can happen simultaneously.

? **In our game the cutting rate increased to satisfy a rising demand for goods, while the planting rate remained constant. In real life, would the owner of the forest have planted more trees?**
Encourage students to think about what they would do.

? **In real life, can a forester harvest trees a year or two after planting like we did? If a tree actually takes more than 20 years to mature, how would this delay affect the forester's long term planning and planting rates?**
Again, this is a brainstorming question with many possible responses. In general, the delay from planting to harvesting makes the real-world system much more complex than the game. If there is a rise in demand, the forester will have to wait 20 years to harvest his new trees, so he must always try to plan ahead. (The Rainforest Game, Lesson 8, addresses this issue.)

? **Does the Tree Game remind you of other similar situations?**

- *Christmas tree farming—harvesting and planting to meet projected demand*
- *Rainforest cutting—clearing forests faster than they can grow back*
- *Managing other renewable resources or agricultural products—balancing how much is produced and how much is used*
- *Managing your money –balancing what you earn and what you spend so you won't run out*

* * * *

Two other lessons in *The Shape of Change* build on the Tree Game: The Tree Game Puzzle and The Rainforest Game. Below are brief descriptions of these two related curricula.

The Tree Game Puzzle

Introduction

This puzzle is an extension of the Tree Game (Lesson 6). After playing the Tree Game, students explore what happens to the number of trees in a forest following a variety of planting and harvesting policies. Math skills include computation, making and interpreting graphs, problem solving, and communication.

How It Works

As teams of students experiment with their simulated forests, they invent their own planting and harvesting rules, collect data based on those rules, graph the results, and see what those graphs reveal about the rules. All of the rules and graphs are posted separately. Students match them up, explain their reasoning, and think about the long-term consequences of various resource management policies.

The Rainforest Game

Introduction

In this simulation game, students act out the lives of trees. Following different planting and harvesting policies, they learn about delays in managing a renewable resource. Math skills include recording data in tables, graphing, predicting outcomes and describing patterns of behavior over time.

The Rainforest Game can be part of an interdisciplinary unit on rainforest resources and inhabitants. It can also complement other science, social studies, economics and ecology units on the sustainable use of any renewable resource.

The Shape of Change *is published by the Creative Learning Exchange, ©May 2004. Illustrated by Nathan Walker, this book presents eleven attractively illustrated and formatted classroom activities. It is available from: The Creative Learning Exchange, 27 Central Street, Acton, Massachusetts 01720. 978-635-9797. The lesson plans are also available individually on the CLE website.*

http://www.clexchange.org

stuntzln@clexchange.org.

Does a Model Facilitate Learning? continued from page 5

The *basic structure* is clear on the left of Figure 1, while admittedly less so on the right. The difference reflects the stage of development. The left-side version is studied by the students in the second week of the course, while the right-side is the end product of a full semester's construction project.[3]

User Interface. It should be emphasized that *MacroLab* is not a management flight simulator in the tradition of *People Express* (Sterman 1988), nor does it resemble natural resource management games like *Fish Banks* (Meadows *et al*., 1993). It is an instructional tool in a distance-learning course where students receive minimal guidance from an instructor.[4] With each new unit, *MacroLab* uses STELLA's "story" feature to display and explain the structure of sectors being added to the model, and suggest new behavior that can be expected. After reading the story (at home), students participate (at home) in simulation activities that compare behaviors of evolving structures while exploring traditional macroeconomics topics. They answer questions designed to assess understanding of model structure revealed in the story, model behavior observed during simulation experiments, and the connection between structure and behavior. Later, the students post their answers online, using the *Blackboard* distance learning technology. Some suggested solutions are available to aid the students during the activities, and instructor feedback is emailed soon after completion.

Designing a user interface—and simulation activities—for the distance learner with neither an economics nor system dynamics background has been challenging, but it has also imposed (and continues to impose) requirements for clarity and simplicity that have probably made *MacroLab* a more useful tool than it otherwise might be.[5] For the experiment discussed in this paper, the standard interface was simplified even more to minimize distraction for the participating subjects.

3. The GDP Experiment

Purpose. The purpose of the experiment is to compare the learning that takes place with three different methods of delivering essentially the same information about gross domestic product (GDP) to three groups of subjects. The three delivery methods are (1) simple narrative only, (2) the same narrative, accompanied by a diagram revealed in stages, and (3) the same narrative and diagram, accompanied by a simulation activity.

Subjects. Three variations of the GDP experiment involving 147 subjects were conducted in Massachusetts and Virginia over a six-month period from November 2003 to May 2004.[6] The November experiment was conducted in Massachusetts at Harvard Public Schools ("HPS" experiment), with participation by 68 junior and senior economics students in three different classes. The April experiment involved 58 students (ranging in age from 17 to 54) enrolled in four different classes of political science and macroeconomics at Virginia Western Community College in Roanoke, Virginia ("VWCC" experiment). The May experiment was joined by 21 junior and senior computer science students at Hidden Valley High School, also in Roanoke ("HVH" experiment).

Procedure. Subjects were randomly assigned to groups and pre-tested. In the HPS and VWCC experiments, subjects were assigned to the three groups (Group 1, Group 2, and Group 3). For reasons explained in the appendix, the HVH subjects were divided into just two groups (Groups 2 and 3).

The research design called for pre-testing to be completed at least a day earlier than the actual experiment, but that did not always happen, with the result that many subjects took the pre-test immediately prior to the experiment, and then took the post-test immediately after the experiment. It is possible that those subjects may have been more likely to give post-test answers that were the same as the pre-test answers. If so, then learning gain would be underestimated in those cases. To the extent that those subjects were randomly distributed among the groups, however, any "pre-test" effects should not affect differences observed between groups.[7]

The experiment for each group involved use of STELLA's story feature. Thus, all subjects were required to navigate to an instructions page and read their learning objectives. All had to click on a button that activated a story about GDP, and all had to "press the spacebar" to progress through their particular story.

Each page in the story read by Group 1 subjects contained text-only information about the meaning of GDP, its measurement, and how it fits in an overall economic system as a concept of "production." Group 2 subjects read a story with the same textual information as Group 1, but the Group 2 story was accompanied by an unfolding stock-and-flow diagram that revealed the structure of a simple economy in a manner to complement the narrative.

Group 3 read the same story as Group 2; i.e., the participants got both the narrative and the unfolding stock-and-flow diagram. However, when Group 3 participants finished the story, they activated a simple simulation exercise designed to reinforce a key point in the story about the relationship between production (GDP), inventories, and final sales. (The validity of the Group 3 results is questionable, however, and those results are discussed only in the appendix.) After each group finished its version of the experiment, post-tests were taken. The "learning gain" for each group was measured as the difference between average pre- and post-tests scores for that group.

Variations in Content and Procedure. Of necessity, most experiments go through a research and development phase in order to “iron out” the wrinkles in both procedure and content, so as to enhance the reliability and validity of the results. The GDP experiment is still in that R&D stage. After the HPS experiment debriefing, it was decided to simplify the experiment in two ways. First, the pre- and post-test questions were reduced in number, an effort was made to clarify them substantially, and a few questions that were problematic or less useful were deleted or replaced. As a result of those changes, the three questions below (with correct answers underlined) were the only questions that were the same in all three experiments:

1. The definition of GDP is the total value of…
   (a) final gross profits produced within a nation during a year.
   (b) final profits, less depreciation, produced in a nation during a year.
   (c) <u>final goods and services produced in a nation during a year.</u>
2. The relationship between GDP, sales, and inventories is most like the one between…
   (a) profits, taxes, and depreciation.
   (b) <u>deposits, withdrawals, and bank balances.</u>
   (c) imports, exports, and exchange rates.
3. A rising GDP tends to raise income and then sales, which increases GDP again.

(a) <u>True</u> (b) False

These questions are obviously simple, but they are intended to probe three different types of learning. Question 1 is a straightforward factual question, where merely recalling information contained in the “story” would produce a correct answer. Question 2 seeks awareness of an analogous relationship, and it requires a higher-order level of thinking than mere recall. No such analogy was stated in the narrative information read by participants in Group 1. Likewise, there was no *explicit* analogy accompanying the “unfolding model structure” observed by Group 2 participants. However, among the elements in that structure are two stock-and-flow relationships that have been extracted from the model and reproduced below in Figure 2.

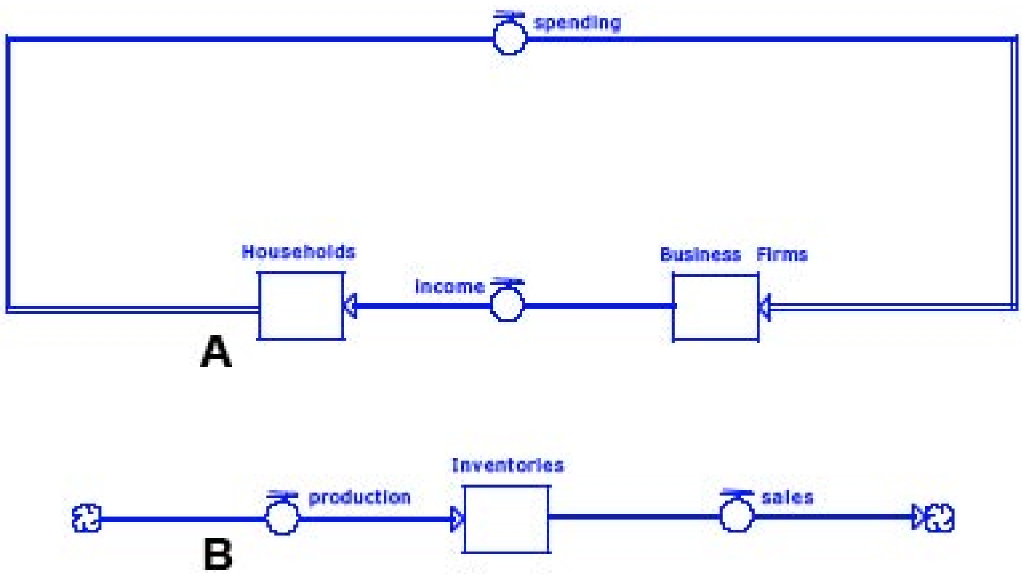


figure 2

The top relationship (A) refers to the flow of dollars from business bank accounts to household bank accounts when income payments are made to the factors of production, and the return flow of dollars when those households purchase goods and services from businesses. The bottom relationship (B) refers to the flow of goods and services in the production process into an inventory stock that is reduced by subsequent sales. The textual narrative (available to both groups) mentions both types of stock and flow relationships, but not in the same context and not in a way that would imply an analogous relationship. However, this *visual* analogy is present for participants in Group 2.

Question 3 attempts to probe the participants' sense of dynamics—the behavior of GDP over time. In the narrative available to both Groups 1 and 2, it was emphasized that GDP (gross domestic product) is the *production* of final goods and services, so that information was the same for both groups. Also exactly the same for both groups was a series of statements that traced the impact of production on income (with a delay), the impact of income on sales (with a delay), and the effect of sales on production (delay), with the conclusion that “…production, income, and sales are part of a mutually-reinforcing process.” However, Group 2 had access to an unfolding loop that accompanied that narrative (figure 3).

4. Results of the Experiment

Recall the different experimental treatments for the two groups. Group 1 read a “STELLA story” containing a text-only narration. The Group 2 story had the same narrative, but was accompanied by unfolding stock-and-flow diagrams.

Hypothesis:

Group 2 would demonstrate more learning gain (as measured by the difference in pre- and post-test scores) than Group 1.

The general results of the experiment are consistent with the hypothesis.

In the HPS experiment in Massachusetts, participants in Group 2 gained an average of 30 points between pre- and post-tests, compared to an average gain of

Model *continued on page 10*

Does a Model Facilitate Learning? *continued from page 9*

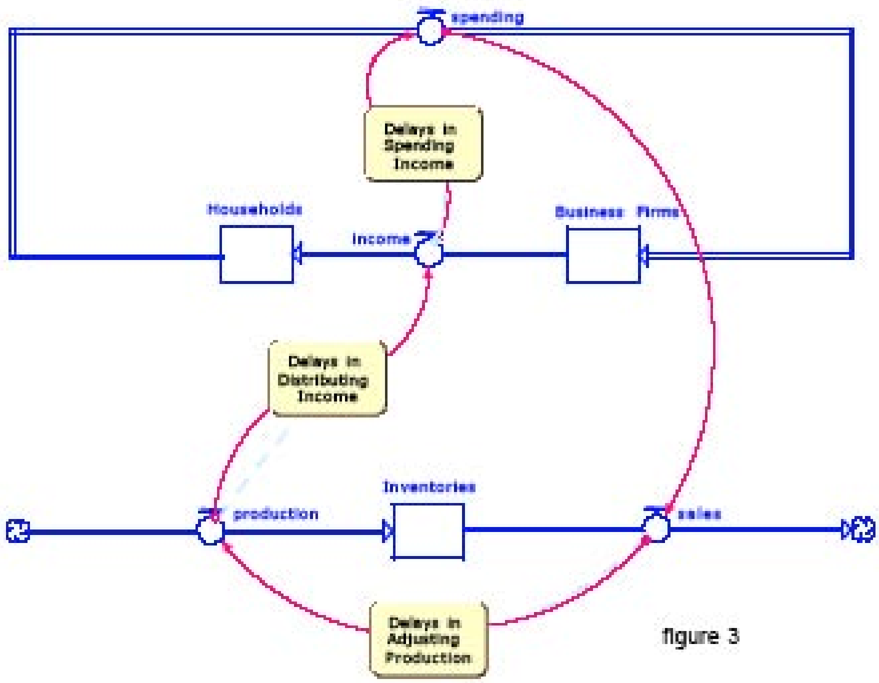


figure 3

15 points by Group 1 participants.[8] Use of a one-tail t-test for statistical significance suggests that the probability of this result occurring by chance is 8 percent.

A similar result was found in the VWCC experiment, but the Group 2 margin over Group 1 was smaller, and not statistically significant. The average Group 2 score also improved 30 points, but Group 1 increased by 24 points ($p < .28$; one-tail t-test).

Combining the results of the HPS and VWCC experiments enables a larger sample, but raises a number of experimental and statistical issues regarding the comparability of the two groups. Thus, at this stage in our analysis, such a combination is presented as merely suggestive of statistical significance ($p < .07$) rather than a confirmation. The learning gains are displayed graphically in Figure 4.

5. Conclusion

The results of this experiment, while tentative, suggest that a model—a simplified representation of reality—can facilitate learning. In this case, the facilitation appears to be provided by simple diagrams that reinforce narrative text. Both Groups 1 and 2 received behavioral descriptions, but only Group 2 was permitted to see diagrams of structure that could infer such behavior. Other experiments are planned for *MacroLab*, and one will be aimed at more explicit testing of the connection between struc-

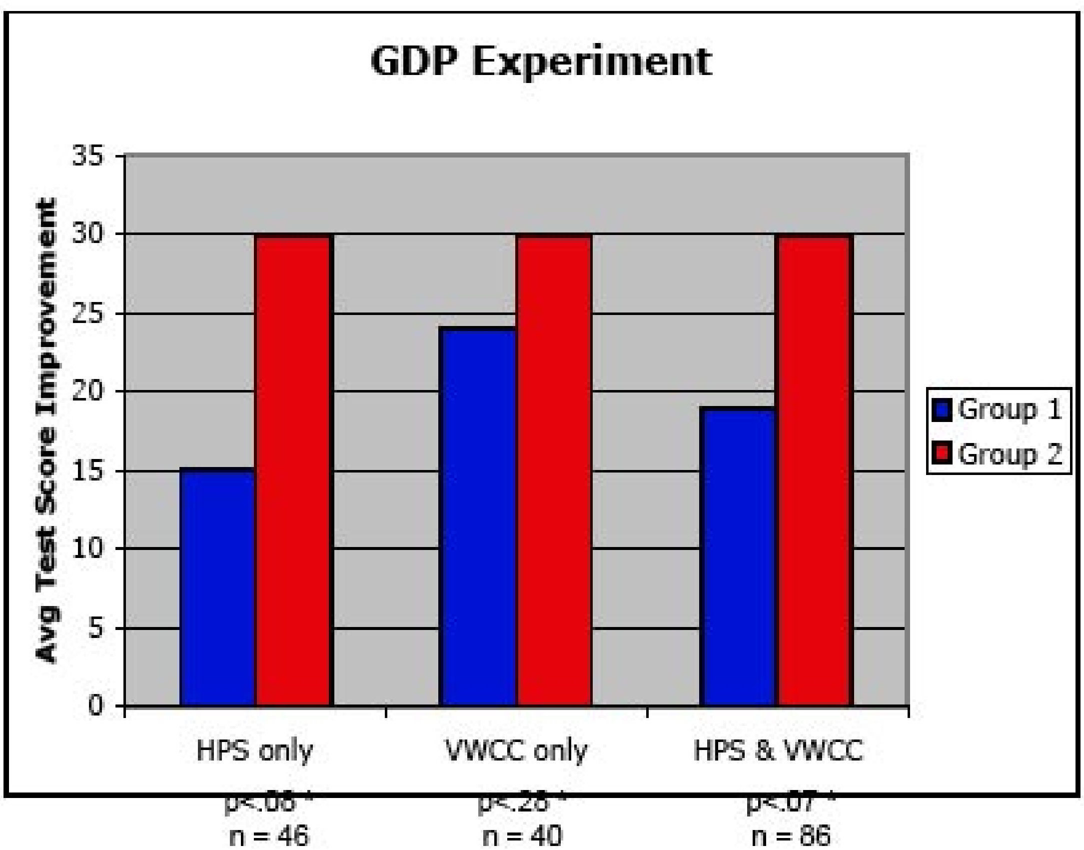


figure 4

* one-tail t-tests

tural understanding and behavioral understanding, with the latter measured in terms of explanations and/or predictions of simulation patterns.

Interested readers are encouraged to contact the authors with comments on this experiment, as well as suggestions for the design of future experiments.

Appendix

The validity of Group 3 results is questionable. The results are provided here, however, along with a discussion of the issues surrounding that portion of the experiment.

Group 3 participants read the same story as Group 2 (i.e., they got both the narrative and the unfolding stock-and-flow diagram). However, when Group 3 subjects finished the story, they activated a simple simulation exercise designed to reinforce a key point in the story about the relationship between production, inventories, and sales.

After the HPS experiment, the simulation activity for Group 3 was simplified to reduce the subjects' required manipulation of control buttons, switches, etc. Those requirements appeared to be a serious distraction and source of frustration for the HPS subjects in Group 3, according to those who administered and monitored the experiments. Moreover, since Group 3 demonstrated *less* learning gain than the other two groups, we concluded that the excessive "management" of the simulation activity might have interfered with the learning process for Group 3. These content changes were put into effect for the VWCC and HVH experiments.

Despite the content changes, the VWCC subjects in Group 3 still fared poorly, compared to Groups 1 and 2. Further consultations with specialists in cognitive psychology, led to another revision—elimination of an "extra" task for Group 3.

In the HPS and VWCC experiments, Group 3 subjects had a pencil-and-paper assignment during the simulation activity. The pencil-and-paper exercise had been conceived as a means to optimize the benefits of that activity. However, we saw that the exercise added considerably to the total time that Group 3 was spending on the overall experiment, and we were concerned about tiring the participants and exceeding their attention spans. We also suspected that the exercise itself might be causing more confusion than clarity. So, we eliminated the pencil-and-paper exercise during the Group 3 simulation activity in the HVH experiment. Due to the small number of subjects in the HVH experiment, only two instructional methods were tested—those for Group 2 and Group 3 (i.e., there was no Group 1 in the HVH experiment).

In the HVH experiment, for the first time, Group 3 showed a strong learning gain. Both Groups 2 and 3 improved average scores by 27 points (about the same as the 30 point gains by Group 2 in each of the HPS and VWCC experiments).

However, the hypothesis that Group 3 would learn *more* than Group 2 was not supported. It may be that the simulation exercise is just too simple to produce any measurable effects, when coupled with the simplicity of the three questions. Moreover, a potential design flaw in simulation display could be causing some problems. The graph displays production and sales—two flows that are easily understood. However, the graph also shows a flow that is fairly easy to grasp in narrative form but may be more of challenge when presented graphically: a *change* in inventories. When inventories are rising at a decreasing rate (e.g., when production is slowing down to match a fall in sales), the graph of "change in inventories shows a downward trend even though the stock of inventories is still rising (albeit more slowly). We think that is confusing the Group 3 participants, who have had no training in stocks and flows prior to exposure to such concepts during the experiment.

Thus, the current Group 3 results are probably not meaningful. Future experiments will attempt to improve the design so as to achieve valid results.

Footnotes

1 David Wheat, Virginia Western Community College, is also a PhD student at the University of Bergen, in Norway. Larry Weathers and Robin Goldstein are from the Harvard, MA Public Schools.

2 STELLA is a registered trademark of isee Systems (www.iseesystems.com)

3 Most link-forming arrows have been omitted to improve clarity. Those shown are in the main reinforcing feedback loop for economic growth (or decline). STELLA's diamond-shaped icons contain sub-models of various decision processes, within which most of the counteracting feedback loops operate. Figure 1 displays a closed economy, but an international sector will be added during the fall semester, 2004.

4 MacroLab will be used in a regular classroom setting for the first time during the Late Fall 2004 semester. During the Spring 2005 semester, a microeconomics version (MicroLab) will take shape. At Worcester Polytechnic Institute, Jim Lyneis (jmlyneis@WPI.EDU) already uses system dynamics to teach microeconomics.

5 For a current description or a demo copy of MacroLab, contact David Wheat (dwheat@wheatresources.com).

6 In this paper, the focus is on the features common to each experiment.

7 The results have not yet been reviewed to determine if such randomness can be assumed.

8 "Points" refers to the percentage of correct answers. Thus, in the HPS experiment, the average Group 1 pre-test score was 57 percent (57 points out of 100), while the average post-test score was 72 (72 points out of 100). The learning gain, then, was 15 points.

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David Wheat, Virginia Western Community College
Larry Weathers, Harvard, MA Public Schools
Robin Goldstein, Harvard, MA Public Schools

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