TUCK EVERLASTING

System Dynamics, Literature, and Living Forever

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INTRODUCTION

In this lesson, sixth grade students use system dynamics tools to explore themes in a novel. *Tuck Everlasting* by Natalie Babbitt is an enchanting and suspenseful story about a child named Winnie who faces big decisions when she encounters the Tuck family and learns their secret about a spring whose water gives eternal life. After reading the novel, students use behavior over time graphs to discuss their own opinions on the story's major themes. They also use a simple system dynamics computer model to see what would happen to the population of the town in the story if people could live forever.

Using these system dynamics tools in a literature unit allows students and teachers alike to make connections across subject areas. Students use their mathematical intelligence in a language arts setting. They also learn that basic systems principles and tools apply across disciplines.

BACKGROUND

Carolyn Platt is a sixth grade language arts teacher in Carlisle, Massachusetts. She developed the population-modeling lesson with the help of Rob Quaden, a Carlisle systems mentor supported by the Waters Foundation. She developed the behavior over time graphing lesson with the help of Rob Quaden, fellow Waters systems mentor Alan Ticotsky, and Debra Lyneis.

These lessons are simple and mostly self-explanatory. However, the Carlisle sixth graders had been previously introduced to behavior over time graphs and basic modeling. If you or your students need more information on these skills, consult the following lessons free on-line from the Creative Learning Exchange at http://www.clexchange.org. (Use "Search" to find them.)

- "Getting Started with Behavior Over Time Graphs: Four Curriculum Examples," by Gail Richardson and Debra Lyneis. The beginning of this paper provides general guidelines for drawing behavior over time graphs, including graphs of soft variables.
- "The In and Out Game, A Preliminary System Dynamics Modeling Lesson" by Alan Ticotsky, Rob Quaden and Debra Lyneis. This lesson explains stock/flow diagrams, graphing and the basic mechanics of STELLA modeling.
- "Everyday Behavior Over Time Graphs" by Gene Stamell with Debra Lyneis. This paper shows how this tool can be used throughout an elementary curriculum.

OBJECTIVES FOR STUDENTS

- Students will use behavior over time graphs to identify and explain what changes over time in the course of the novel, *Tuck Everlasting.*
- Using their graphs, students will discuss their opinions on issues in the story such as fear, courage, trust, maturity, and the acceptance of death.
- As a class and in teams at computers, students will build a simple model of the population of Treegap, the town in the story. They will use the model to explore what happens to Treegap's population if people can live forever. They will also relate this population growth to their own local area.

(objectives, continued)

- Students will use evidence from their model to write about the consequences of living forever, relating it back to the novel.
- By using system dynamics tools in a literature unit, students will learn that systems principles and tools are transferable across disciplines.

PREPARING FOR THE LESSON

Time Requirements

- One class period for the behavior over time graphs lesson.
- One class period for the modeling lesson, plus a follow-up classroom or homework writing assignment.

Materials

- Copies of the book:
  - *Tuck Everlasting* by Natalie Bobbitt, A Sunburst Book; Farrar, Straus and Giroux, 1975.
- For the graphing lesson:
  - Story chronology sheets to review the sequence of events in the story.
  - Behavior over time graphs worksheets.
  - Pencils, colored markers, paper.
  - Easel pad and marker, or blackboard and chalk.
  - Overhead projector and transparencies, or blackboard and chalk.
- For the modeling lesson:
  - One computer with a projection device or large screen, or an overhead projector, or blackboard and chalk.
  - STELLA© system dynamics modeling software available from High Performance Systems, Inc., 45 Lyme Rd., Suite 200, Hanover, NH 03755. Tel. 603-643-9502. http://www.hps-inc.com. (There is a free run-time version of STELLA available from the website. You can use it to build the model; you just cannot save your work.)
  - Computers at which students can work in teams. One computer for every two students is ideal, but use whatever you have.

LESSON 1: BEHAVIOR OVER TIME GRAPHS

Setting the Stage

Briefly review the chronology of events in the story. So that their graphs will be consistent, students should remember what happened on the first day, the second day, etc. Use the following chapter summaries to refresh their memories. Ask students to take turns reading the summaries aloud in their groups, noting on their copies when one day ends and the next begins.

Name__________________

TUCK EVERLASTING
By Natalie Babbitt

Chapter Summaries

1. Road to Treegap.
2. Mae Tuck sets out to meet sons.
3. Winnie Foster thinks about running away.
4. Man in yellow suit is looking for someone.
5. Winnie meets Jesse, Miles and Mae.
6. Tucks kidnap Winnie.
7. Tucks tell Winnie about living forever.
8. Man in yellow suit overhears the story.
9. Arrival at Tucks' home. Winnie meets Angus Tuck.
10. Winnie tours Tucks' messy house.
11. Silent pancake dinner.
12. Tuck explains dangers of living forever. Horse is stolen.
13. Man in yellow suit tells Fosters that Winnie is okay.
14. Bedtime. Jesse proposes to Winnie.
15. Man in yellow suit offers trade: Winnie for the wood.
16. Constable on his way to Tuck's.
17. Winnie goes fishing with Miles.
18. Man in yellow suit arrives.
19. Man wants Winnie. Mae hits him with rifle.
20. Constable arrives. Mae could be hanged if man dies.
21. Winnie home again. Man in yellow suit dies.
22. Jesse gives Winnie water. Winnie has idea to save Mae.
23. Hot night. Storm brewing. Midnight at last.
24. Mae escapes and Winnie takes her place.
25. Weeks later. Winnie pours Jesse's water on toad.

Epilogue. Many years later, Tucks return to Treegap.

What Changed Over Time in the Story?

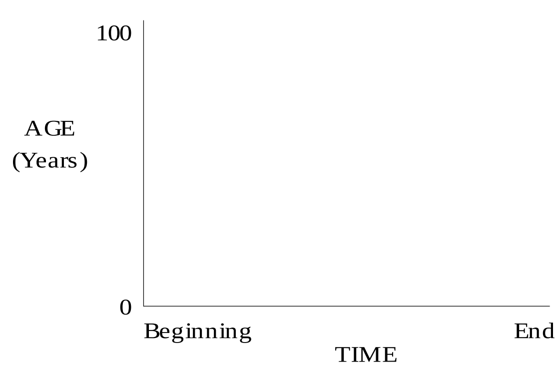
Ask students to think about the scene at the beginning of the story and the scene at the very end, including the epilogue. What things changed during the story? Let students brainstorm as many ideas as they can as you write them down on the easel pad or blackboard. Changes can be concrete or abstract. They can encompass the entire story or just part of it. The only requirement is that you record the students' suggestions as *nouns--- they must be specific quantities that can increase or decrease over time.* These are typical responses:

- The population of Treegap
- The size of the wood
- The amount of development in town
- Winnie's age
- The ages of Miles's children
- The ages of the Tucks (which did not change after they drank the water)
- Winnie's fear
- Winnie's trust in the Tucks
- Winnie's "prissiness"
- Winnie's independence
- Winnie's courage
- Winnie's maturity
- Winnie's acceptance of death
- The Fosters' trust in Winnie
- The Tucks' love for Winnie
- The "evilness" of the man in the yellow suit (as revealed to the reader)

How and Why Did It Change?

Students will draw graphs to describe how some of these variables changed over time. Start as a class with the age changes because they are more concrete and because they will more closely relate to the graphs students have done in their math classes.

1. On the overhead projector or blackboard, draw a vertical and horizontal axis. Remind students that a behavior over time graph is just a rough sketch; it is a way to look at patterns of behavior rather than at exact numbers. Distribute the following worksheet to students.
   - As you label the axes together, remind students that *time must always be on the horizontal axis* on a behavior over time graph. On this first graph, time goes from the "Beginning" of the story to the "End" (including the epilogue).
   - The vertical axis is for the variable you are studying. Label it "Age in Years," 0-100. (Do not label every point on the scale—focus on the patterns, not the details.)



BEHAVIOR OVER TIME GRAPHS Name________________________

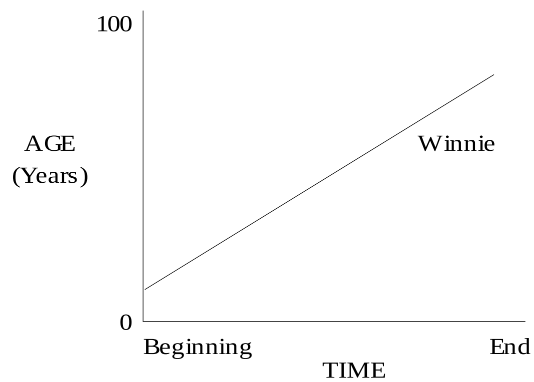
Clearly label your graphs.
Use the other side of this paper to draw more graphs.

1.

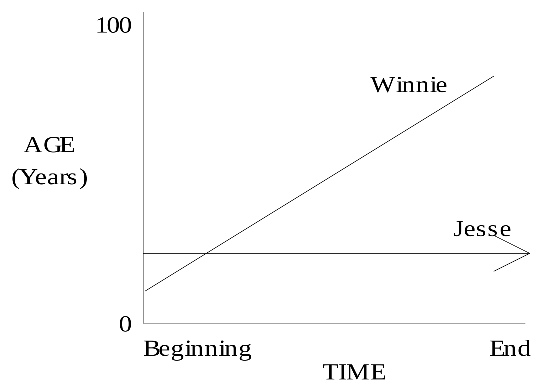
2.

3.

2. Ask students to graph Winnie's age from the beginning of the story (age 10) to her death in 1948 at the age of 68. (This can be somewhat confusing to students since the action in the story covers only three days and Winnie's death many years later is only revealed in the epilogue. Ask students to consider how Winnie's age changed from year to year throughout her lifetime, similar to their own grandmothers' ages.) Mark a starting spot on the vertical axis representing 10 years. (If students need more guidance, also discuss where Winnie's final age might be.) Allow students to finish their own graphs before discussing their ideas as a class.

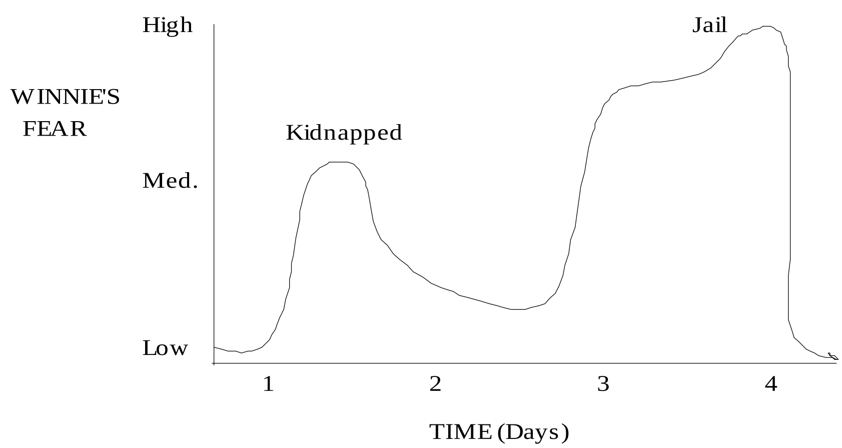


3. Graph Jesse's age. (If students are confused by the concept of age, discuss that aging means to grow one day older every day. After the Tucks drank the water, they may have lived for many years, but they never aged. Their ages remained unchanged forever.) Together mark a starting spot on the same graph for Jesse's age, 17, and let students draw their lines before discussing them as a class. Note the spot where the two age lines intersect--this is when Jesse hoped that Winnie would drink the water and marry him. Note also that Winnie's line ends at 68 years, while Jesse's continues forever.



4. If students need more practice, quickly graph other ages. Miles and his children are similar to Winnie and Jesse. Students are especially intrigued by the frog's age: It grew until Winnie sprinkled the water on it; then it ceased to age. If students consider the Tucks' ages starting when they were born, their patterns are similar to the frog's.

5. Students are now ready to graph some of the more complex changes in the story. Start with Winnie’s fear.
   - On a new graph, label the horizontal axis with the days of the story. The story opens one evening and takes place over the next three days. Label the vertical axis “Winnie’s fear,” ranging from “Low” to “High.” Define these in discussion. “Low” means no fear at all. “High” means “scared to death,” terrified.
   - Ask students to work in their groups to produce larger graphs with markers, so that the graphs can later be displayed, compared and discussed.
   - Students should decide how frightened Winnie was at the beginning of the story and draw their graphs to show how they think her fear increased or decreased as the story unfolded. They do not need to be particular about details—this is just a quick graph. (Limiting their time to just a couple minutes forces them to draw quick rough graphs rather than focussing on details.) Students may label important points on the graph. They may refer to the chapter summaries worksheet to recall when events took place.
   - Emphasize that there are no right or wrong answers; this is a way to express their own opinions. Graphs may vary from group to group.
   - A typical graph might look like this:



6. Display the graphs so that students can observe and discuss the differences. (Another option is to have students superimpose their different lines on the same graph in different colors on the overhead projector or blackboard, explaining their reasoning as they draw their lines.) Issues like these come up:
   - How could students all read the same book and reach different conclusions on how frightening events in the story are?
   - Why do most students think that taking Mae’s place in jail is more frightening than being kidnapped? What makes those events frightening? How would they feel?

7. Deepen the discussion by asking students to draw a related line on the same graph.
   - For example, ask students to graph Winnie’s courage on the same graph as her fear and observe how students view the relationship differently. How is courage different from fear? How did Winnie become more courageous? Once you gain courage, can you lose it? Does facing your fears cause you to become more courageous? Can you be courageous and frightened at the same time? What does this mean to you?

- Another interesting variable is Winnie's maturity. Use a graph to explore how and why it grew. What happened to make Winnie more mature? What does it mean to be mature? Graph another variable such as Winnie's independence or her acceptance of death on the graph of her maturity to discuss how these are related.
- Use the graphs to explore any variables, to help students express their views explicitly, and to focus the discussion. Whenever possible, graph related variables on the same graph to help students think about interrelationships and the causes of change. Expect and accept that individual student graphs may differ widely. Use these differences to help students express, clarify and defend their own views in an objective way.

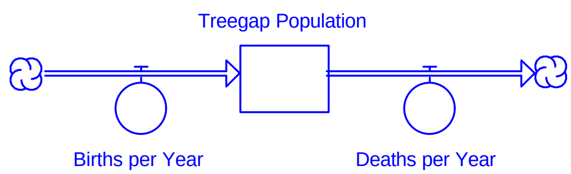
LESSON 2: BUILDING THE MODEL

In earlier class discussions while reading the book, students have weighed the idea of living forever, the novel's main theme. Now, using a system dynamics model, students will examine what would happen to the population of Treegap if everyone could live forever.

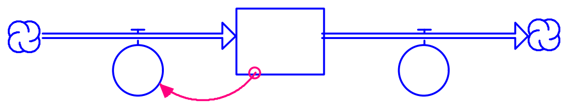
1. Decorate a box as a time machine and explain to students that they will be writing letters to send back in time to either Winnie or the man in the yellow suit. They will use the information that they will learn from their modern computer models to write their letters.

2. Ask students for the big decision in the story: whether or not to drink the secret water and make it available to others. The model will help them explore what would happen to the population of Treegap over time if everyone drank the water and lived forever.

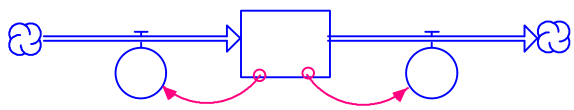
3. Using a computer with a projection device, build the model together as a class. (Complete models in STELLA versions 5.0 and 7.0 are also provided with this lesson.) Prompting students to review what they have learned about STELLA modeling, drag a stock onto the screen and label it "Treegap Population." This is the number of people in the town.
   - Does the number of people always stay the same? What makes it change?
   - Births increase the population. Add an inflow for "Births."
   - Deaths decrease the population. Add an outflow for "Deaths."
   - Ignore migration for simplicity in this model.



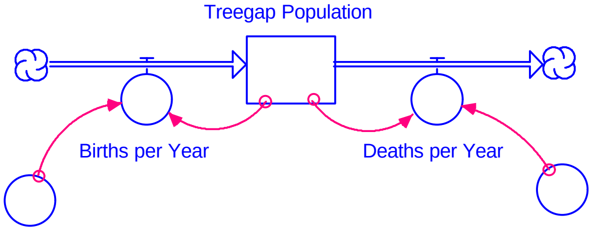
4. Ask students to consider how births increase the population? Does the size of the population have an effect? Are there more births in a larger population? Discuss how the number of babies born depends on the number of people and draw a connecting arrow from "Population" to "Births." This is called *feedback* because the size of the population influences the birth rate. Trace this loop and read it aloud: the more people, the more births, therefore the more people, etc. This is a *reinforcing loop* because the growth builds on itself. (Be sure to spend enough time on this important point.)



5. Similarly, how do deaths change the population? Does the number of deaths depend on the number of people? Draw the arrow from "Population" to "Deaths." Trace and read aloud this loop: the more people, the more deaths, the fewer people, the fewer deaths, the more people, etc. This is also a *feedback loop*. This one is a *balancing loop* because the change works around the loop to restore the first change--it balances out.



6. Ask students what else affects the number of births and deaths. Students will suggest factors such as the ages of the people, how many are female, health care, etc. Explain to students that people who study populations often group all of those factors together and call them "Birth Rate" and "Death Rate." These rates determine what percentage of the population is born or dies each year. Add converters for these and draw arrows connecting them to the "Births" and "Deaths" flows.



7. Now it is time for equations. Remind students to click on the globe icon in the upper left corner of the screen to change it to x^2. Question marks on the model indicate that we need to supply more information there.

- For "Treegap Population," click on the stock and enter an initial population of 500. The units are "people." (This model uses population figures from our town, Carlisle, Massachusetts, which had a population of approximately 500 in 1880, the time of the story. We are guessing that this number is reasonable for Treegap too. Relate this to a local small town or to another area familiar to your students.) Click OK.
- The birth rate is 6%. Discuss that this means that there are 6 births for every 100 people every year. Written as a decimal, this is .06. Click on the converter and enter .06 for "Birth Rate." The units are "people/year." (Again, these figures approximately match Carlisle's growth.)
- The death rate is 4%. This means that there are 4 deaths for every 100 people every year. Enter .04 for "Death Rate." The units are "people/year."

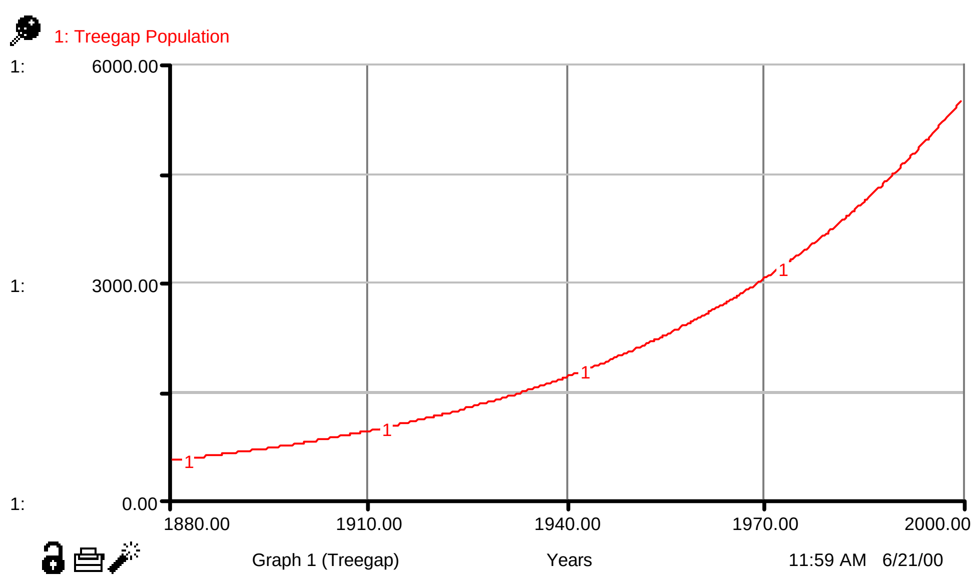
- Ask students to derive the "Births" and "Deaths" flow equations. If there are 6 births for every 100 people every year, and you have 500 people, how many births will there be? What is the operation? Births = Population x Birth Rate. Likewise, Deaths = Population x Death Rate. Click on the flows and enter the equations by highlighting the required inputs.

8. Set up the graph. Drag a graph icon onto the screen and click to open it. Double click on the graph, highlight 'Treegap Population," and click on the arrow to select it. Click OK.

9. From the "Run" menu, select "Time Specs." Enter the length of simulation from 1880 (the beginning of the story) to 2000. Label the time units "Years". This labels the horizontal axis. Click OK.

10. The model is complete, but there is one last *essential* step before running it. Ask students to draw a behavior over time graph labeled from 1880 to 2000 and predict how they think the population will grow and what final value it will have in 2000. Students should discuss their predictions and reach a consensus in their teams. This is just a prediction, a quick *best guess* that will help them think about their own model results later.

11. After students have committed their estimates to paper, send them to their computers in teams to build the model and run it themselves. Students can usually do this very quickly, but there are a few common technical mistakes.
    - If there are "clouds" where the flows should join the stocks, students need to "dynamite" the flow and draw it again making sure to drag the flow completely *into* the stock before releasing it.
    - The birth flow arrow must flow *into* the stock; the death flow arrow must flow *out.* They are computed in the direction they are drawn, regardless of labels.
    - Be sure that all red connecting arrows flow in the correct directions.
    - The graph should look like this:

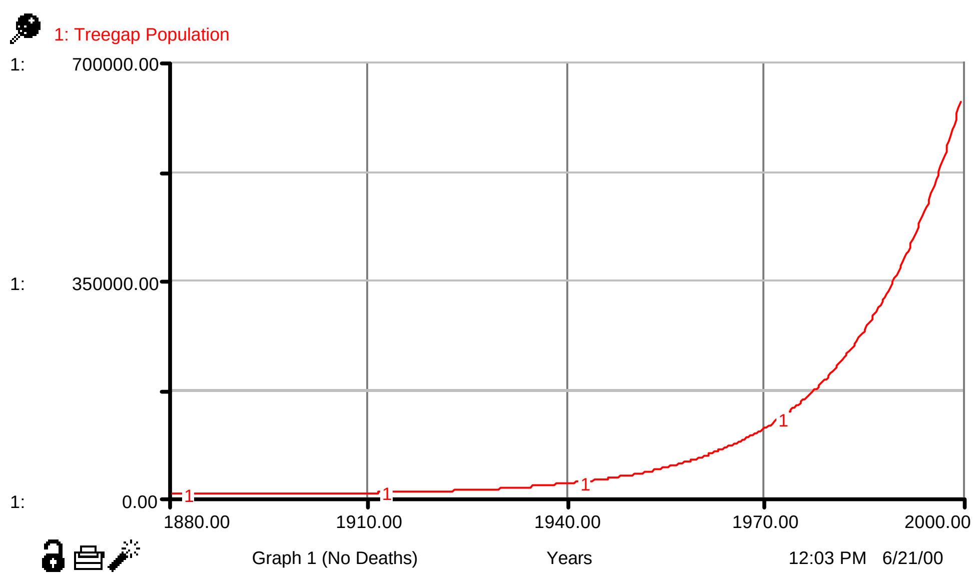


12. As you circulate among the teams of students at the computers, ask them questions to stimulate their thinking about the model. Building the model itself is just the beginning—students need to probe what they can learn from it. Tailor the difficulty of questions for different students and use their findings to lead an ensuing class discussion. Some questions might include:
    - How does your prediction compare with the model results? Why are they different?
    - What is the Treegap population in 2000? (They should estimate this from the graph, *not* from a table. Graph reading is an essential system dynamics skill.)
    - What is the population at other specific points on the graph?
    - Why does the line curve up? Why is it “flatter” at first and “steeper” at the end?

13. Bring students back into a class discussion.
    - How did their estimates compare with their model results? What population did they find for 2000? This number approximately matches Carlisle’s current population. Relate this to a local area familiar to your students.
    - Why does the line on the graph curve up? Ask students to discuss this in their teams. They eventually express the idea of exponential growth: Because the growth rate applies to a larger and larger population, the population grows more and more quickly over time. There are more births than deaths each year. A larger population has more babies.

14. Return to the story, *Tuck Everlasting*. What happens to people if they drink the water? How could students use the model to find out how this would affect the population of Treegap? What would happen to the death rate if people lived forever? Let students see that the Death Rate would become zero. Before allowing students to run the model again, ask them to *predict* the change in the population in their teams on a behavior over time graph.

15. Examine and discuss the results of the model again, in teams and then as a class.
    - What happened to the population and why?
    - How accurate were their predictions?
    - Why did the population on the model grow so fast?



16. Relate what students have learned to the real world. In Carlisle's case, the population in 2000 is about 5000, approximately the projected size of Treegap in the first run of the model. In the model with no deaths, however, the population grew to nearly 700,000, which is approximately equal to today's population of the city of Boston (not including the greater metropolitan area). What would it be like in our rural town if that many people lived here? What about schools, roads, water supply, sewage, forestland, etc.? Let students discuss the consequences and limits of over-population, relating these same issues to your town or neighborhood.

17. Finally, relate what students have learned back to the novel. For their follow-up classroom or homework assignment, ask students to write a letter to either Winnie or the man in the yellow suit explaining what they know about living forever. In addition to explaining what they have learned from earlier class discussions, they should also be sure to include current information learned from the model. They must give either character their best advice, trying to convince Winnie or the man in the yellow suit to make a good decision about distributing the water. Place the finished letters in the "time machine" for their delivery back in time to Treegap.

CONCLUSION

This lesson uses a very simple population model. In Carlisle, students use similar models in a third grade science/social studies lesson about the extinction of ice age mammoths, in their fifth grade endangered species projects, and in a seventh grade biology lab on the growth of yeast in test tubes. They also see a similar exponential growth patterns in math models of bank accounts. Through these lessons, students begin to recognize and discuss the familiar patterns. Each lesson reinforces the concept that the structure of the system produces the behavior, and that the same basic structures are transferable across disciplines.

YOUR FEEDBACK

We would appreciate your comments or any suggestions for improving these lessons. Please send them to us at LyneisD@clexchange.org. Thank you.