EVERYDAY BEHAVIOR OVER TIME GRAPHS

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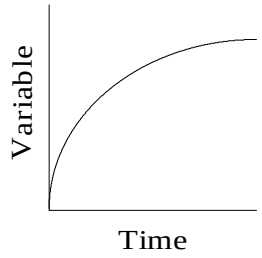
INTRODUCTION

Gene Stamell, a third grade teacher in Carlisle, Massachusetts, uses behavior over time graphs throughout his curriculum. These graphs have become a tool in his teaching repertoire, and his students are becoming adept at using them to broaden and sharpen their thinking about change over time. This paper will give general suggestions and specific lessons for using behavior over time graphs in language arts, math, social studies, and science. Gene hopes to show other teachers that these graphs are easy and worthwhile to use with students.

WHAT IS A BEHAVIOR OVER TIME GRAPH?

A behavior over time graph (or BOTG) is a simple line graph that shows a pattern of change over time – it shows how something increases and decreases as time passes. The horizontal axis on the graph *always* represents time. It can be in any units that fit the behavior: seconds, days, years, etc.



The vertical axis represents the variable in question, a quantity that can increase or decrease with time – an accumulation. It can be either "hard" or "soft." For example, hard variables might be degrees Centigrade in a lab experiment, points scored in a game, dollars in the bank, fish in the sea, or miles traveled. Soft variables could be a person's happiness or courage, a team's morale, the cleanliness of a room, or the excitement of a story. The vertical axis is also labeled in units that fit the behavior. For the hard variables, the units are straightforward: degrees, number of points, number of dollars, etc.

For the soft variables, units must be defined first. "Cleanliness of a room" is a simple example. In discussion, everyone could envision a spotlessly clean room; they could also imagine an extremely messy room. The scale on the graph could use descriptive labels and range from "Terribly messy" to "Perfectly clean," with "Medium clean" at the midpoint. Or, the scale could be numerical from 0 to 10, with zero for filthy and ten for immaculate. Students just need to be clear about what they mean when they label their axes. Soft variables are just as valid to graph as hard variables. Indeed, often they are more interesting, and even defining the scales can initiate a good discussion.

One final thing to remember about BOTGs is that they focus on *patterns* of behavior, not on particular details. They look at how something is changing. Is it increasing, decreasing, or staying the same? At what rate is it changing; how steep is the line? Does it fluctuate? Once students can identify *how* something is changing, they can begin to ask *why* and make predictions about what will happen next.

Because BOTGs focus on broad patterns, they are often drawn quickly. Students are usually encouraged to draw the line freehand without getting bogged down in details. Of course, in graphing a science experiment data points need to be precise, but even then, the purpose of the graph is to reveal the overall pattern of behavior – how it is changing and why. In most cases, students quickly draw their axes, label them, and sketch lines describing how the variable changes with time. They can also draw lines for related variables on the same graph to compare them.

As an example, if students graphed the cleanliness of their own rooms over the course of a week, they would produce many different patterns, stimulating a discussion about why this happens. (Students might also graph the "Amount of Mom's nagging" on the same graph to discuss the relationship between the two variables.) This example shows how students can use a graph to express and objectively discuss their ideas. It also shows that graphs can have many right answers. Finally, it shows that students can use a graph to examine patterns of behavior and their causes. Once students understand how to use behavior over time graphs to analyze one behavior, they can easily transfer the use of this tool to examine change in many other areas.

WHY USE BEHAVIOR OVER TIME GRAPHS?

Gene Stamell and other teachers have found that using BOTGs helps students *broaden* their thinking. Young students tend to focus on events detail by detail; they often do not see the big picture. With BOTGs, students develop the skill to see the forest as well as the trees. Gene has also found that using the graphs helps students *sharpen* their thinking. Finally, graphs give students another way to express and defend their ideas, leading to richer classroom discussions about topics in the curriculum.

Gene is participating in a Waters Foundation effort to assess more formally the impact of BOTGs on student learning. From his own preliminary classroom experience, however, he thinks that BOTGs have helped his students build skills in several ways:

- Students develop math skills reading and drawing graphs. They can read the value of the variable at any point on the line, often using interpolation.
- Students gain an understanding of axes and scales because they have to define them for themselves. They can define and label scales that are appropriate to the behavior being graphed.
- Students learn about slope. They learn that a "steeper" line indicates faster growth or decay; a "flat" line indicates no change. Using this knowledge, they can be more precise when they use a line to describe how something is changing.
- Students can find meaning in graphs. The graphs are not isolated math exercises. They hold information that is of interest to the students because the graphs are in the context of the curriculum or apply to their own lives and opinions.
- Students use BOTGs to make predictions. They can continue the line on the graph to express what they think will happen to the variable in the future. (In contrast, pie charts and bar graphs are more static; they do not lend themselves to the richer discussions of predictions.)

- Students use BOTGs to ask better questions. They question why something changed and what might have caused it.
- Students can generate hypotheses, or "what ifs." After they observe one pattern of behavior, they can discuss what might have happened if something had been different and express these alternatives as lines on the graph. (Third graders *can* think like that, Gene adds, although they are not often asked to do so.)
- Students develop another way to refine and communicate their ideas. Graphs complement reading and writing skills. For some students, they offer a more concrete visual way to form and express opinions.
- Students develop basic systems thinking skills. They learn to think dynamically—to recognize patterns of change over time. This is the first step in beginning to understand what causes that change. The discipline of system dynamics uses computer simulation to investigate those causes. Building a system dynamics model starts with drawing a BOTG of how the behavior in question changes over time; the model ultimately produces graphs as output to interpret. For Gene's third graders, BOTGs are a valuable curriculum tool in their own right. At the same time, however, they lay the foundation for further system dynamics learning by helping students develop skills thinking about "what" is changing, "how" it is changing, and "why" it is changing.

INTRODUCING LINE GRAPHS TO STUDENTS

Third graders are not usually adept at drawing or interpreting line graphs. It is a skill they must learn and practice. In Carlisle, primary (K-2) students learn to use bar graphs and pie charts, a common and concrete introduction to graphing, usually using manipulative materials. They are briefly introduced to line graphs through "The In and Out Game" (by Alan Ticotsky and Rob Quaden, 1999, available from the Creative Learning Exchange at http://clexchange.org.) Second graders also use a line graph to track the daily progress of the Iditarod dogsled races across Alaska. Although they have seen line graphs, arriving third graders are most familiar with bar graphs and pie charts. Early in the fall, Gene builds on his students' understanding of bar graphs to expand their understanding of line graphs. With guidance, third graders make this transition easily.

Reviewing Bar Graphs

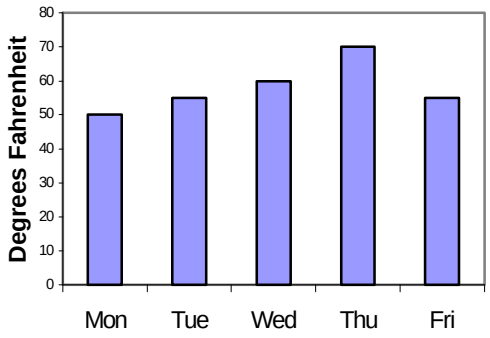
For several mornings, Gene asks students to make graphs to answer daily class questions. At first they draw the graphs together on the board and progress to working in pairs or individually. Each graph stimulates a class discussion about what the graph says and why. Examples include:

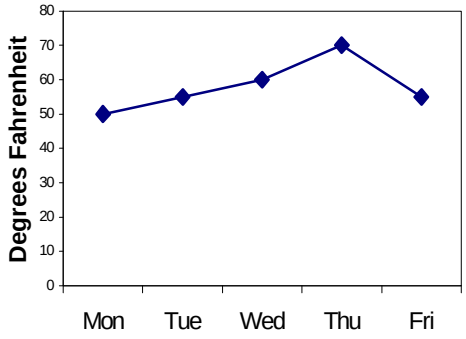
- How many siblings do you have?
- How many pets do you have?
- What color hair do you have?
- What is your bedtime on a school night?
- How many hours of TV do you watch on a school night?

Note that these are all static phenomena. They do not change over time; they do not have time on the horizontal axis. These, however, are typical bar graphs for young students.

Making the Transition to Line Graphs

One way to help students make the transition to behavior over time line graphs is to present a simple bar graph of data changing over time that could be better shown as a line graph. One example is graphing the outside temperature over a five-day period. Students record the temperature each day on a large bar graph on the board. At the end of the week, Gene places a dot at the top of each bar and erases the bars below them, leaving only the five dots on the graph. After the class once again discusses what each dot represents, Gene connects the dots with a continuous line. Then the discussion focuses on the pattern of change from day to day as shown by the line: Has it gotten warmer during the week, or has it gotten cooler? Students also discuss how much easier it is to see the pattern of the temperature change with the line graph than with the bar graph.





This activity is repeated several times with different bar graphs until students can convert bar graphs to line graphs on their own. In each case, students discuss and compare the two types of graphs with questions such as these:

- Which graph do you prefer looking at? Why?
- Which graph gives you a better idea that something is changing? Why?
- Have you ever seen line graphs outside of school?
- When would you rather use a bar graph? A line graph?

Other examples of graphs for this activity include:

- Daily class attendance.
- Number of students buying lunch each day.
- Daily precipitation amounts.
- The number of hours each student watches TV each day for a week.
- The time each student goes to bed each night for a week.
- The number of pages in a book read each night for a week.

The idea is to emphasize the central concept of change over time. Bar graphs have a very static nature. Line graphs are more fluid and accentuate patterns of change as time passes. Once students can identify patterns of change, they can compare patterns and explore their causes. They can ask “Why?” and “What if…?”

Another way to reinforce the purpose of a line graph is to discuss topics for which bar graphs are more appropriate. A bar graph is a good way to count things that do not change over time, like the topics graphed in the first review of bar graphs above. For example, counting and graphing the number of siblings of classmates describes only one moment in time, not a pattern of change over time. Numbers of siblings, not time, is on the horizontal axis. A bar graph is a good way to display this information, but it does not give clues about change. Throughout the year, Gene asks students to decide which type of graph is more appropriate for each activity.

SAMPLE LESSONS

Following are nine examples of how Gene uses BOTGs in his curriculum. They include lessons in literature, science, math and current events. Some are formal lessons taking 30-60 minutes while others are quick 10-minute discussions. They are presented as Gene's students would experience them in a typical autumn. Our goal is to show teachers how behavior over time graphs can be used as an everyday tool in the curriculum. Gene found that once he started using BOTGs with his students, he saw more and more applications for them. We hope that these lessons will help other teachers do the same.

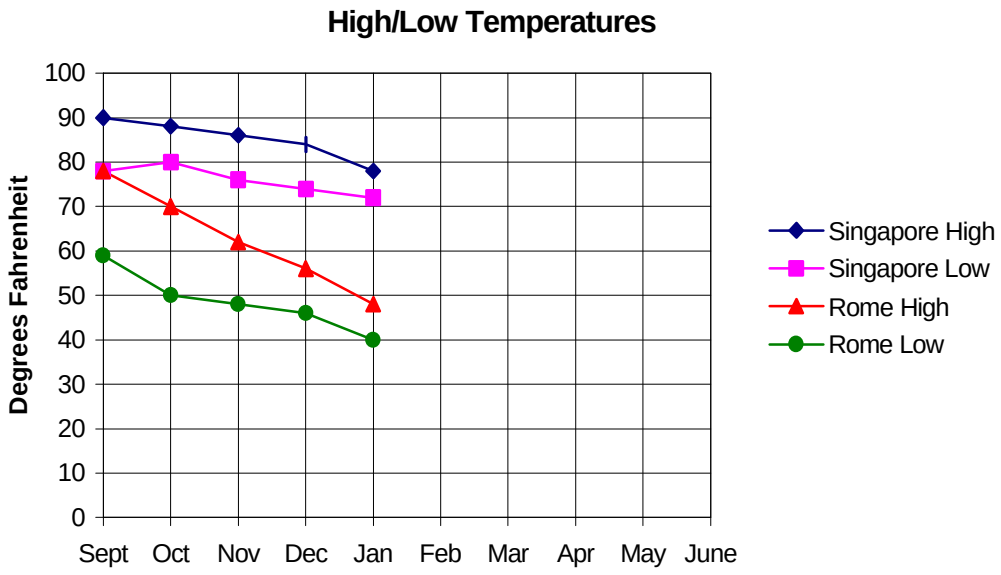
Some of the lessons are presented with specific instructions and student worksheets. Others are described more generally.

1. GRAPHING DAILY TEMPERATURES

Curriculum area: Math
Time requirement: 15 minutes, once a month

As part of their math curriculum, students track the high and low daily temperatures in two cities once a month throughout the year using data from the local newspaper. Early in the fall, each student chooses two cities from around the world. On a lined worksheet, each student records the high and low temperatures for each city once a month.

Gene has added graphing to this lesson. After three months of data gathering, students draw graphs on graph paper. They label the horizontal axis with the months of the year starting with September. They label the vertical axis in degrees Fahrenheit from 0 to 100. They define their own legends distinguishing their cities with different colors or dotted lines. Then, they plot their data of high and low temperatures for the first three months (all on the same graph) and connect the points to draw lines.



Once each month, students research the high and low temperatures, write the information on their worksheets and plot the points on their graphs. As the year progresses, students can observe the patterns that are emerging and discuss questions such as these as a class, in pairs or in groups:

- What does your graph tell you?
- How is the temperature changing in your cities? Why?
- Are there differences in the patterns of your two cities? Why?
- What do you think will happen in the next few months? Why?
- How do your cities compare with those of other students?
- Why do some cities stay warm all year?
- Could you get all of this information just looking at the map?
- Where would you rather look to figure out this information, on your worksheet list of temperatures or on your graph? Why?

For variations, students could track particular cities that are related to the curriculum in other areas. They could relate their findings to a science lesson on climates and seasons. They could also use on-line sources for temperatures.

A complementary exercise would be to have students read a classroom thermometer once each hour for a day and graph the changing temperature. Students would have to change both the vertical and horizontal scales from the graph above, reinforcing their understanding of the scales. Reading the thermometer would reinforce that skill as well as relate the foreign temperatures to temperatures at home.

2. GRAPHING FRIENDSHIP OVER TIME

Curriculum Area: Language arts, poetry
Time Requirement: 30-40 minutes

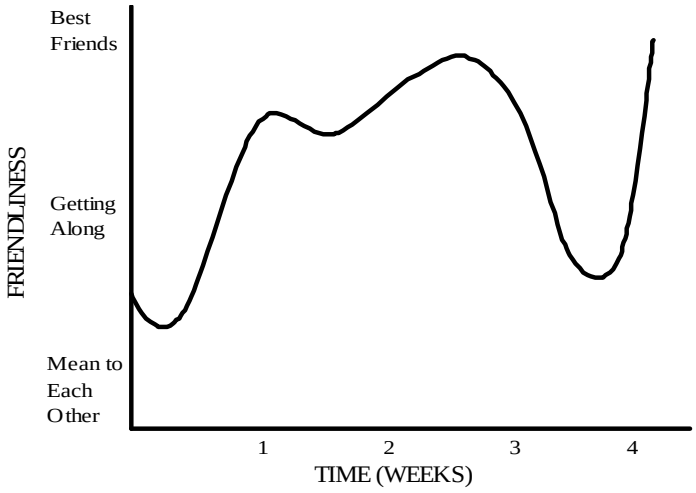
As part of a poetry unit, students read this poem by a former Carlisle third grade student:

Friendship
By Lisa Yanofsky, 1998

New, arriving coming, then
    Older
    Darkens
    Lightens
    Brightens
    Dims
Wonderful
Horrible
My friend is perfect
    Strange
My friend is right for
    Me.

After students have read the poem, Gene begins the class discussion with the question, "What do you think this poem is about?" At length, students discuss the "ups and downs" of friendship. Gene then asks, "I wonder how else we could show that." The poem suggests a graph.

Gene draws a large set of axes on the board and students generate the labels. The vertical axis shows the "Amount of friendly behavior," or "Friendliness" between the two people. Students define the scale in their own terms and discuss what the labels mean in their experience. The horizontal scale represents time; students need to specify what is appropriate – days, weeks or months – sparking another good discussion.



Gene invites students to the board to sketch on the graph what they think the poem says about friendship over time. As several students express their ideas on the same graph, it becomes apparent that there are many different interpretations. Because students are authorities on the subject of friendships, they draw from their own experience. *There are no wrong or right answers*, as long as the line on the graph accurately depicts what they mean. (For example, if they say friendliness is *increasing*, the line should be going *up*.)

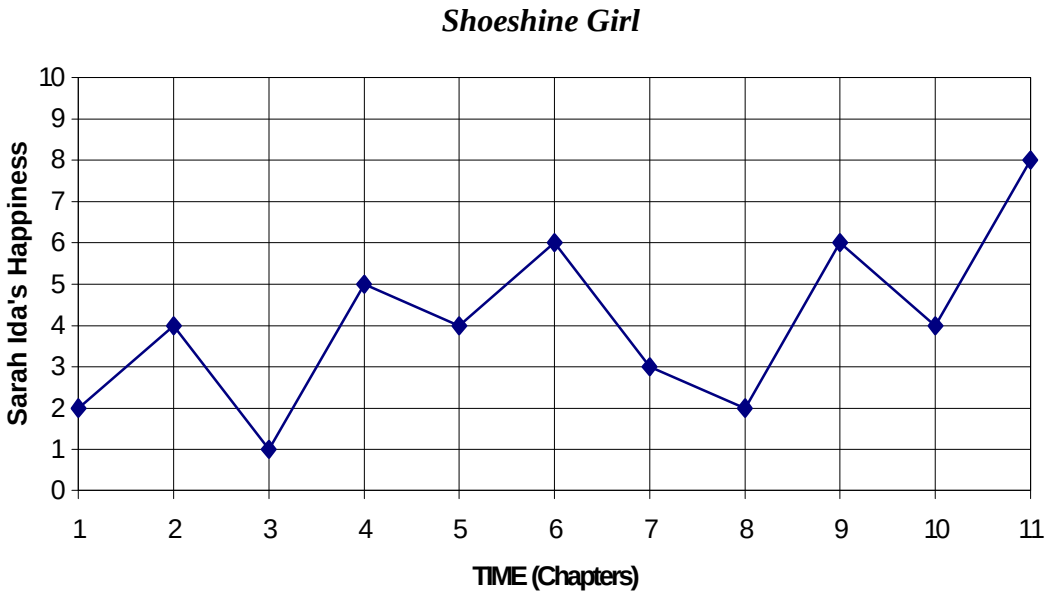
In conclusion, students gain a deeper understanding of the message of the poem and its meaning to their own lives: Friendships are always changing with time.

3. GRAPHING *SHOESHINE GIRL*

Curriculum area: Language arts, literature
Time requirement: 30-40 minutes

All Carlisle third graders read *Shoeshine Girl*, by Clyde Robert Bulla (1975, Thomas Y. Crowell Company, New York.) It is the story of a willful self-centered child named Sarah Ida who learns compassion, responsibility and generosity during her summer working for a shoeshine man.

As the story unfolds, Gene asks students to graph Sarah Ida's level of happiness, chapter by chapter. Each student sets up a graph on a sheet of graph paper. The horizontal axis is labeled from 1 to 11 for the number of chapters in the book. The vertical axis represents Sarah Ida's happiness scale. The class brainstorms labels for this scale in terms that have meaning to them. Some students may use numbers while others may use descriptive labels from "Terrible" to "Terrific," with "So-so," "OK" and "Happy" in between.



Gene begins the graphing by asking students to put a dot on the graph wherever they think Sarah Ida's level of happiness is after the first chapter, sparking a big discussion among students who view the story differently. Again, Gene assures students that there are no right or wrong answers; every student is entitled to an opinion. The process is repeated at the end of each chapter and the dots are connected to form a line. Students often compare and discuss their graphs in pairs or in groups.

The graphing activity generates a good literary discussion at a level appropriate to third graders. It helps to make an abstract concept more concrete for the children. It also encourages students to think about their own interpretations of the story. For example, at age 8 or 9, it is common for some students to dwell on one bad incident rather than view the character's general happiness and maturity over time. Without the graph, students might miss the main idea of the story: Sarah Ida is growing and changing.

Gene conducts a similar lesson with another book, *The Sign of the Beaver,* by Elizabeth George Speare (1983, Bantam Doubleday, NY). It is about a friendship between a Native American boy and a young settler. Gene reads the book aloud to the class. Students graph the developing friendship with a separate line for each boy's point of view. This helps students follow the thread of the story. It also helps them to think about the very different circumstances and perspectives of the two boys as they grow together.

4. GRAPHING SCIENCE OBSERVATIONS: LEAVES

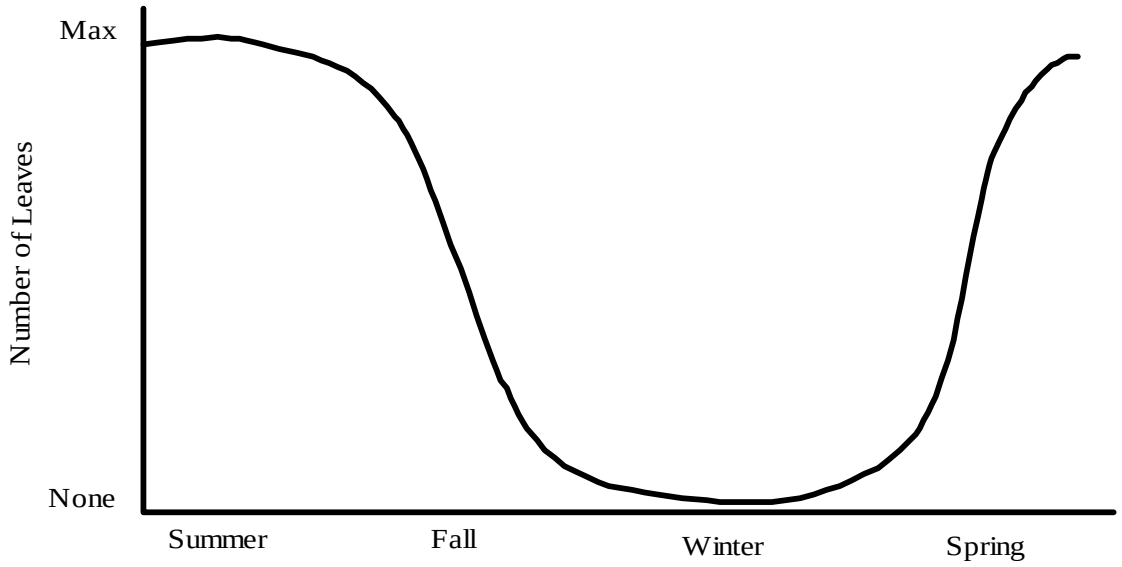
Curriculum Area: Science
Time Requirement: 10-15 minutes

In New England, the leaves on the trees are always changing with the seasons. Throughout the autumn, students do several science activities with leaves. They also make observations and record them in their science journals.

In late fall, students use a large classroom behavior over time graph to examine how the number of leaves on the trees is changing. The vertical axis represents the "Number of Leaves" which ranges from "none" to "the most possible." The horizontal axis is labeled with the seasons "Summer, Fall, Winter, Spring." (The scales do not need to be any more specific at first, because the precise numbers of leaves or the specific dates are not necessary to uncover the pattern of change throughout the year.)

Different students sketch their ideas on the same graph showing what they have observed so far and what they predict for the rest of the year. Again, students are encouraged to take risks and are assured that there are no right or wrong answers. When students draw slightly different lines, the discussion often centers on the slope of the line, with students delving more deeply into the *rate* of the change in leaves as the seasons change. Students may also decide that they need to label the horizontal axis in months to express their ideas more precisely.

Graph of Leaves



5. FINDING STORIES IN GRAPHS

Curriculum Area: Math, building graphing skills
Time Requirement: Homework assignment followed by a 15-20 minute discussion

This exercise helps students stretch their ability to think in terms of graphs. Students are not ready for this activity until they have done several other line graph activities as a class.

Using the following worksheet, students are asked to generate at least five "stories" for an oscillating line. What could this graph be about? Again there are no right or wrong answers, as long as the stories are reasonable.

The following suggestions were given by four students and illustrate the breadth of their thinking as well as the depth of their understanding:

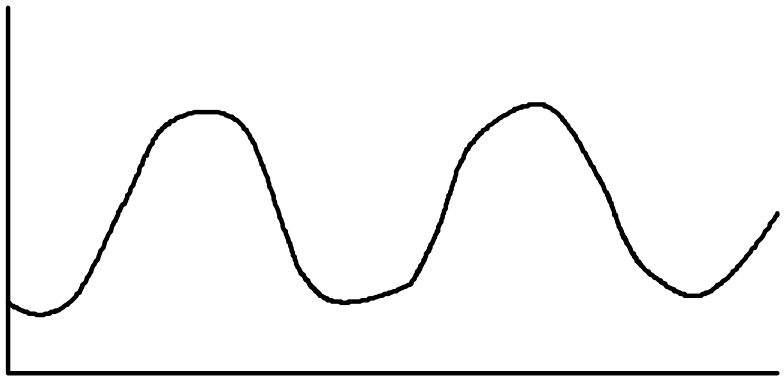
- How well friends are getting along together over months.
- The temperature outside in September.
- How well a toy is selling over a year.
- How clean your house is over a month.
- How happy you are over a week.
- How many boats are crashing every month.
- The amount of friendship in a school.
- How many smokers quit.
- How the 2000 presidential election went up and down for so long.
- How the price of a stock is changing.
- How many points a team is scoring.
- How many heart attacks there are over a year.
- How much air pollution there is over time.
- The temperature as seasons pass.
- How fast a plant grows in different months.
- How much it rains in different months.
- The number of hours of daylight.
- How much food a bear eats during different months of the year.

Name_____

BEHAVIOR OVER TIME GRAPH

Write five topics this Behavior Over Time sketch could be about. What is changing and what is the time measurement?

There are no right or wrong answers. All reasonable answers are correct.



1. _____

2. _____

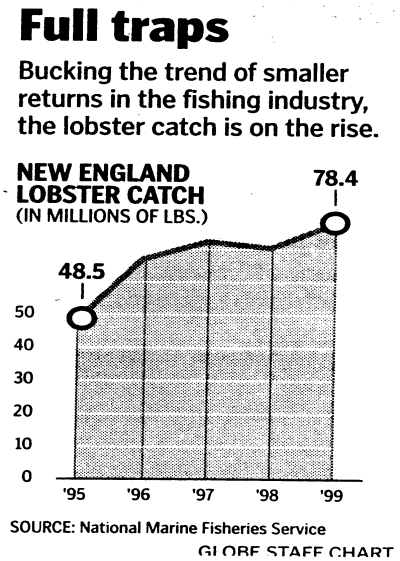
3. _____

4. _____

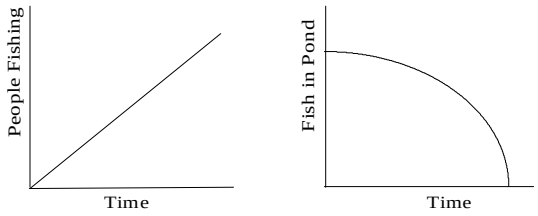
5. _____

6. GRAPHS IN THE NEWS: LOBSTER FISHING

On November 29, 2000, the *Boston Globe* ran an article titled "Abundance of New England Lobsters Baffles Biologists." The accompanying graph showed an increase in the annual lobster catch. In New England, depleted fish stocks are often in the news. Usually students hear that the supply of fish is dwindling as the demand is rising. This *Globe* article is intriguing because it states that the while fishermen are catching more and more lobsters, the population of lobsters seems to be increasing.



Before introducing the article, Gene asked students to think about what would happen to the number of fish in a pond if the number of people fishing there increased every day. Students sketched BOTGs of the increasing fishermen and the decreasing fish population.



Then Gene handed out copies of the *Globe* headline and graph. Together they read the graph, and students proposed their own theories for the abundance of lobsters. Finally, Gene gave them the scientists' theories to evaluate:

- Warmer temperatures cause more lobster eggs to hatch.
- There are fewer predator fish, like cod, to feed on lobsters.
- There may be hidden female lobsters that avoid traps and produce many eggs.
- When lobstermen catch lobsters, they use bait like herring and other bits of fish. Smaller lobsters may enter the traps, eat the bait, escape, and live longer.
- Lobsters may be producing eggs at a younger age than before.

The graphs help students focus on a new twist to a familiar story in regional current events. They are drawn into the mystery and encouraged to think about its causes.

7. GRAPHS IN THE NEWS: SCOOTER INJURIES

Time Requirement: 30-40 minutes

On December 8, 2000, the *Boston Globe* published an article titled "2 Scooter Models Recalled As Reports of Injuries Mount." The Consumer Products Safety Commission had found rising injuries linked to handlebar design flaws. A line graph accompanied the article.

Gene photocopied the graph without its legend and scales. (See the worksheets on the following page.) He asked students to describe what this graph could be about and to define the time units. These were some of the student responses:

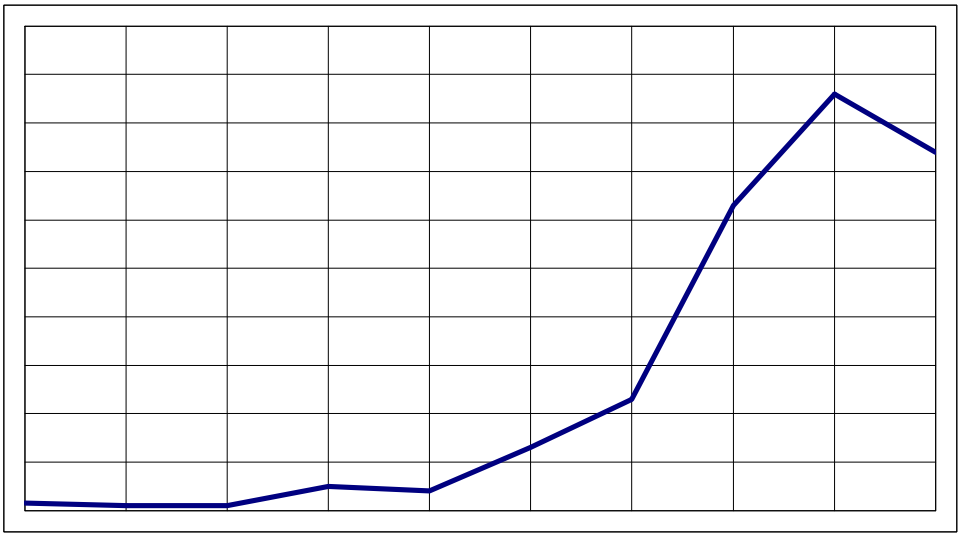
- Progress construction workers are making building a house. Months.
- Number of people buying tickets to a sports game. Years.
- Number of points scored by a football team. Weeks.
- Number of homeless people. Years.
- Number of rainstorms. Months.
- Toys sold at a toy store. Months.

After discussing the students' ideas and heightening their interest, Gene distributed copies of the actual graph. Students read the complete graph together as a class. Gene then asked them to suggest reasons for the pattern of rising injuries. These were some of the student responses:

- "In January, scooters just came out and no one had one, but then a lot of people got them and tried tricks and got hurt."
- "Maybe around school time kids ride scooters to school, and with a coat and backpack and with cars dropping other students off, they can get hurt."
- "Some people are doing more stuff that scooters are not made for like trying to ride on the grass and snow or trying to do dangerous tricks without any safety equipment to look cool."
- "Maybe older kids don't wear equipment and they are teaching that to their younger siblings. Kids are taking bigger risks that they are not ready for."
- "Scooters are getting more popular, and more, and more, and MORE, so there are more injuries."

Finally, Gene asked students to predict what would happen in the next few months by extending the line beyond the edge of the graph and writing a sentence explaining their reasoning.

What could this graph be about? What is the time measurement?



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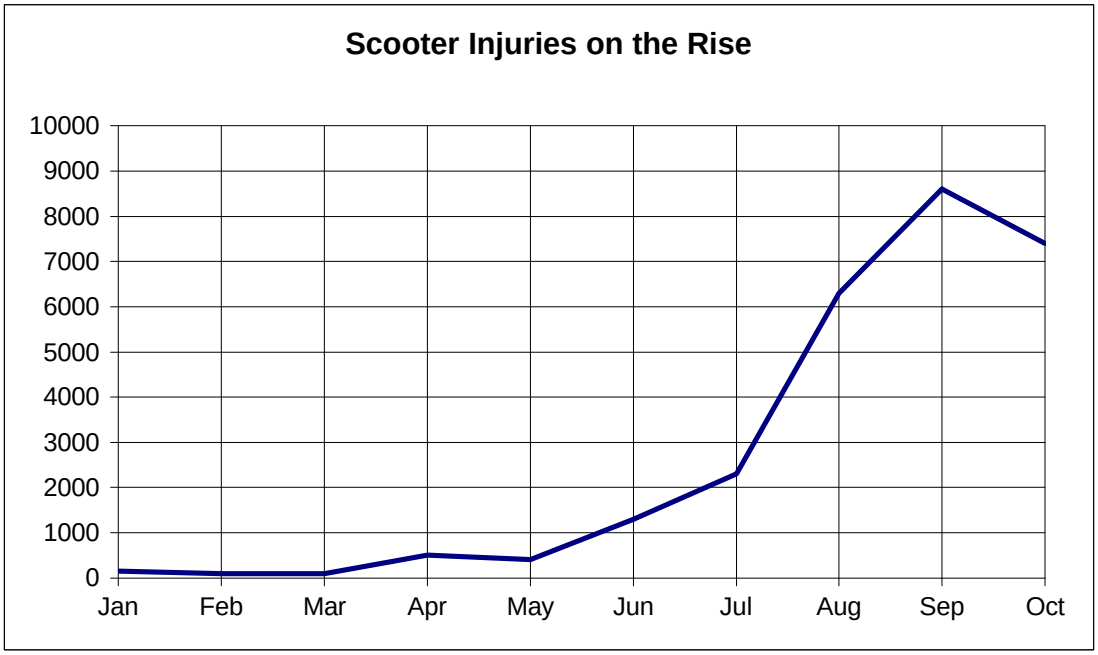


"Emergency rooms nationwide saw a sharp increase in injuries during the year from lightweight scooters popular with children." Consumer Products Safety Commission. *Boston Globe* 12/8/2000

Give 3 reasons why scooter injuries are increasing as shown on the graph.

What will happen next, and why? Continue the line on the graph for Nov. and Dec.

8. MORE GRAPHS IN THE NEWS

Throughout the year, Gene is always looking for good examples of graphs in the news. While some become the basis for complete graphing lessons like those described above, others make good ten-minute "quickie" lessons.

- **Voter turnout trends.** During the 2000 presidential elections, there were graphs about trends in voter turnout and other election issues. Students read the graphs and discussed possible reasons for the trends.
- **Student dropout rates.** A graph of student dropout rates led to a discussion about why students might choose to leave school and the possible consequences of that decision.
- **Income and happiness.** A graph about a study of the relationship between income and happiness over many decades led to a discussion about why rising affluence had not lead to a commensurate increase in happiness.

In each case, the graphs helped students get to the heart of the matter quickly. They could discuss current events objectively while building their graphing skills.

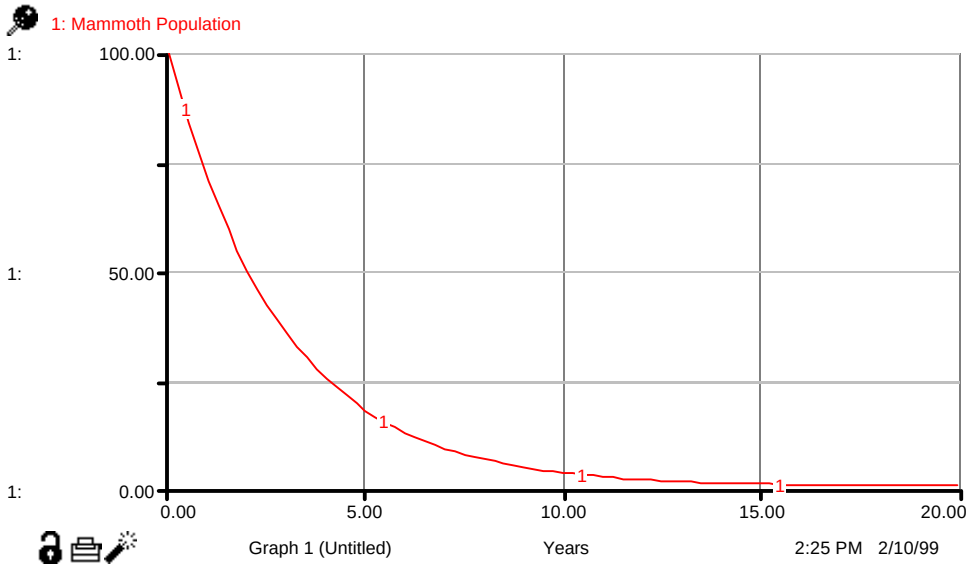
9. THE MAMMOTH EXTINCTION GAME

Curriculum Areas: Social studies, math, science
Time Requirement: Two 40-minute periods

The Mammoth Extinction Game is a lesson using dice, graphs and a system dynamics computer simulation to study the effects of human hunters on the demise of the prehistoric wooly mammoth population in North America. Gene developed the lesson in 1999 with the help of Carlisle Waters Foundation systems mentors Alan Ticotsky and Rob Quaden. The complete lesson with student worksheets and modeling instructions is available to download for free from the Creative Learning Exchange at http://clexchange.org under Cross-Curricular Materials on the List of Materials.

In the dice game, students graph the decline of their own mammoth herds (20 dice) over several years. The next day, they play the same game on the computer varying the probabilities of birth and death. They predict outcomes and eagerly interpret the behavior over time graphs generated by the model. Their engagement and sophistication are impressive. Along with sharpening their graphing skills, they learn the fundamentals of population dynamics, they are introduced to computer simulation as a tool for problem solving, and they are exposed to the concepts of exponential growth and decay.

The following is an example of a graph generated by the STELLA© simulation model:



CONCLUSION

We have presented examples of how Gene Stamell uses behavior over time graphs across his third grade curriculum in the early months of the school year. After an introduction and a little bit of practice, the students become very skilled at using the graphs to both understand patterns of change and express their ideas about them. In the broader picture, students come to notice patterns of change in the systems that surround them. They also move toward a deeper questioning and understanding of the causes of change and the possible policies to manage it – ideas that will be reinforced in later systems lessons.

As Gene continues to use graphs with his students throughout the year, we hope that these sample lessons will help other teachers do the same.

Note: For more examples of BOTGs in fifth grade social studies and language arts, see "Getting Started with Behavior Over Time Graphs: Four Curriculum Examples," 1998, by Gayle Richardson with Debra Lyneis, available free on-line from the Creative Learning Exchange at http://clexchange.org.

YOUR FEEDBACK

We welcome your comments and any suggestions for improvements on these lessons. Please e-mail us at LyneisD@clexchange.org. Thanks.