D-4776

Getting Started with Behavior Over Time Graphs:

Four Curriculum Examples

Prepared
With the support of the
Gordon Stanley Brown Fund

Administered by the
Creative Learning Exchange

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May, 1998

Available from
The Creative Learning Exchange
1 Keefe Road
Acton, MA 01720
978-287-0070

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Introduction

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

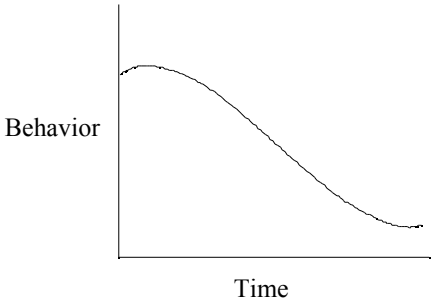
Why Use Behavior Over Time Graphs?

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

How to Get Started

The Graph

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



The Variables

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

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

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

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

How to Teach a Lesson Using Behavior Over Time Graphs

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

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

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

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

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

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

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

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

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

Advice and Encouragement from Gayle Richardson

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

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

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

SAMPLE LESSON: "The People Could Fly"

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

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

Materials: Paper, pencils

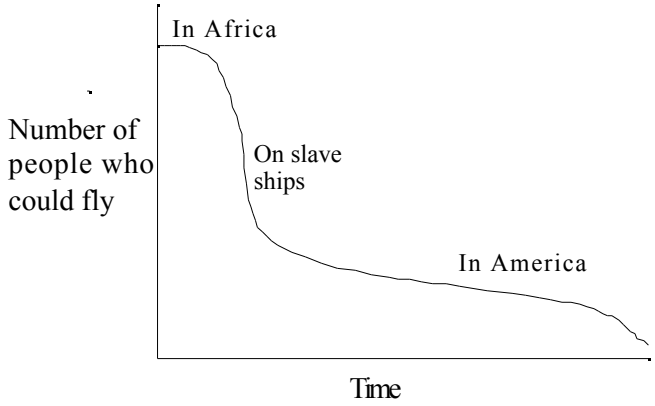
The People Could Fly: American Black Folktales, told by Virginia Hamilton, illustrated by Leo and Diane Dillon, Alfred A Knopf, NY, 1985.

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

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

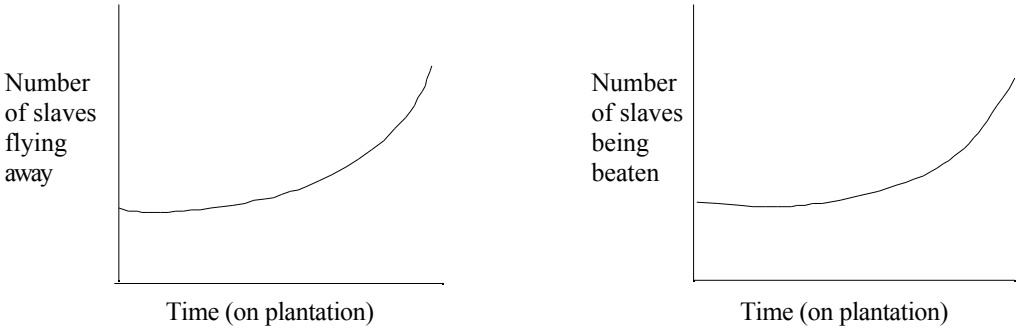
Activity:

- Read "The People Could Fly" aloud to the class. (It is short, about 5 pages.)
- What changed? Ask students to list things that changed over time in the story and write them on the board. Examples from students: number of slaves on the plantation, number of people who could fly, the master's satisfaction with the overseer, the master's anger, the beating down of slaves. These are the variables. (Remind students to think about "what changed, how it changed, why it changed" by writing these questions on the board.)
- How did it change? Ask students to graph a change in groups or individually. (If this is new to students, you may want to demonstrate one together as a class.) What happened to the number of people who could fly, for example? Help students to be sure that their graphs say what they want them to say.

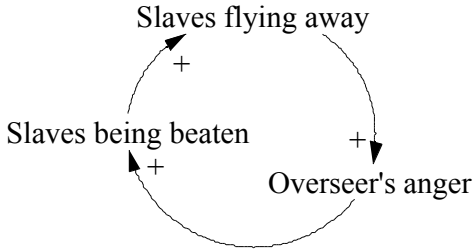


- Why did it change? Ask students to share their graphs and use this as an opportunity to explore the story in depth as they explain their view of what happened and why. Why did the number of people who could fly go down when they were enslaved? Why did it go back up? Children get very engaged in this. You can guide their learning by looking for differing views on the same variable and asking students to explain their own ideas.

- Compare graphs of related variables to find relationships; for example, as the master's anger rises, so does the overseer's cruelty to the slaves, and the number of slaves flying away. Why?



- Ask students to look for causal loops. This may be more difficult for students, but here is one that suggests itself. This causal loop diagram says that the more slaves fly away, the more angry the overseer gets, the more the slaves are beaten, the more they fly away, and so on. Each arrow represents a causal relationship. The plus sign means that the change is in the same direction. An *increase* in the number of slaves flying away causes the overseer's anger to *increase*. (Also, a *decrease* in the slaves flying away would cause the overseer's anger to *decrease*.) This is a positive loop; the behavior keeps spiraling, reinforcing itself.



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

SAMPLE LESSON: Cinderella

Curriculum Area: Language Arts

Objectives: Students will use behavior-over-time graphs to identify the basic pattern of a fairy tale. From the graphs, they will learn about the elements of a good story in order to write their own good story. They will write, publish, and illustrate a humorous fractured fairy tale including some elements of the genre (good and evil, beautiful and ugly, 3's, royalty, increased confidence, security or happiness of the main character).

Materials: Paper and pencils
"Cinderella," original Grimm version, plus modern versions
Other fairy tales, old and new, from a variety of cultures

Time required: This unit takes several days for instruction, plus time to publish stories.

Activities: These are described in general so that other teachers can adapt these ideas to their own curriculum.

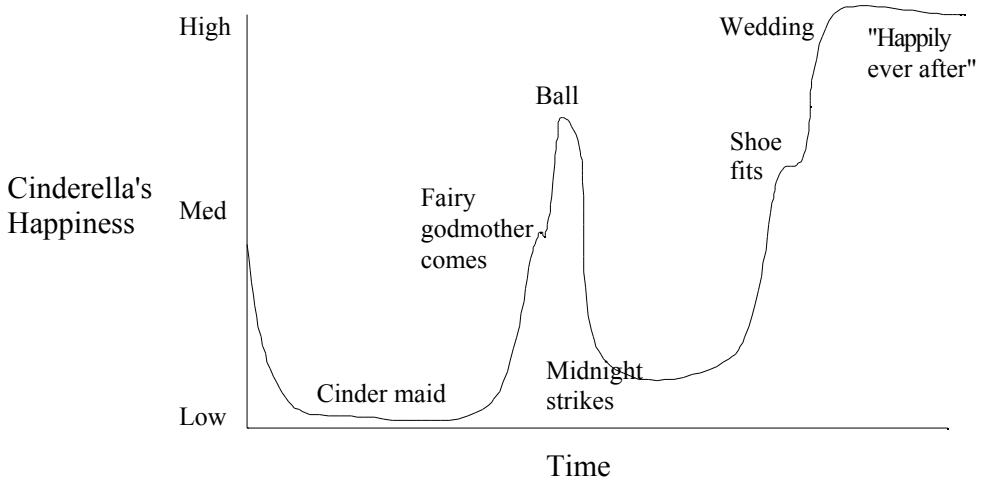
What is a fairy tale?

- As a class, brainstorm a list of favorite fairy tales.
- Identify the conflict in each story. What is the main character's wish and what is interfering with its attainment?
- Create a web of various story elements frequently found in fairy tales. (Inspiration mapping software works well for this.) Examples:
  - Obvious antagonist and protagonist.
  - Moral or lesson
  - Good always wins over evil
  - Magic
  - Royalty
  - Things happen in 3's
  - Begins "Once upon a time"; ends "happily ever after."
- List some broad themes that change over the course of the story such as: happiness, friendship, fear, health, loneliness, satisfaction, confidence, competence, etc. (This works best if children look at the class list of favorite tales and try to figure out the themes.) Students see that happiness or a happy life is the goal of most fairy tale main characters.

Cinderella

- Read "Cinderella" (Grimm) aloud to the class. Note the major events in the story with the students. Make a behavior-over-time graph of the story.
  - What changed? Ask them to find things that changed as the events unfolded. Some examples might be the meanness of the mother, the jealousy of the sisters, the happiness of the prince, the happiness of Cinderella. Focus the discussion on Cinderella's happiness as a central theme.

- How did it change? As a class, ask students to graph how Cinderella's happiness went up or down with the events. Time (the sequence of events of the story) plays out on the horizontal axis. Cinderella's happiness, is on the vertical axis, with the scale defined as "Low," "Medium," "High." In the story, Cinderella's happiness is at rock bottom when she becomes cinder house cleaner to her father's new wife. Her happiness is sky-high when she marries prince charming. There are ups and downs in between. Help students get the flow of the pattern of change. Do not focus on every little dip in the graph.
- Why did Cinderella's happiness change? This comes out as students



discuss and negotiate just how their graph should look. Give students enough time for this discussion and they will easily explore why the changes are important to the story and how all the relationships are intertwined.

Other Fairy Tales

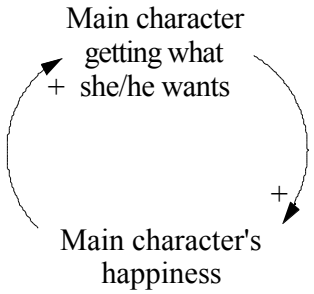
- After students see the pattern of the Grimm Cinderella, ask them to compare it to the Disney version or versions from other cultures. Discuss similarities and differences as they relate to their graph.
- Assignment: Have each student or group of students read a different fairy tale and develop a behavior-over-time graph of the happiness of the main character throughout the story. Have students compare their graphs. If you use large newsprint for the graphs, you can post them around the room and ask each group to explain theirs to the class. These were our findings:
  - Students were intrigued by the similarities and differences among their graphs, from story to story.
  - Students discovered that all fairy tales have a happy ending. "Happiness" has ups and downs but it always ends up.
  - Students found that it is better to have some ups and downs for a good story. A story with a flat line is boring.
  - This is a good entry to discuss the elements of a good story.

Fracture a Fairy Tale

- Knowing the elements of a good story, what could students fracture in a fairy tale and still keep those elements? Discuss the meaning of the word "fracture" as it relates to their stories and to their graphs.
- Read some fractured fairy tales such as The Stinky Cheese Man (Scieszka, John, The Stinky Cheese Man and Other Fairly Stupid Tales, Viking, NY, 1992). Create a web, similar to the one created for fairy tales, of the elements of these stories. These students discovered that humor is an essential element of a fractured fairy tale. Discuss which elements could be fractured, referring again to their graphs from the previous exercise.
- Assignment: Plan a fractured fairy tale, write a rough draft, revise, and publish it with illustrations. We used a planning worksheet to help students to:
    - Choose a fairy tale (with its graph pattern.)
    - Specify which elements will change and how. Choose among time, place, culture, characters, conflict, or other elements.
    - Describe the rising action using the graph chosen, noting any changes.
    - Include some of these elements: special beginning, royalty, magic, threes, special ending, etc.
    - Have all of these plans approved by the teacher before writing.
- Peer evaluation: Ask students to read their stories to small groups of peers who will create their own behavior over time graphs of the fractured tale and help students make sure that all the necessary parts are included.

Note: Using graphs in this lesson helps students understand fairy tales in depth. It also builds their system dynamics skills by helping them to look for patterns of change in behavior over time. They recognize similarities and differences in those patterns and they learn that outcomes can be manipulated. This is quite straightforward in fairy tales where the patterns are obvious and predictable, but this practice will help students spot behavior over time patterns in more complex systems later. This same approach could be used with other literature genres.

Causal loop diagram:
Near the end of this unit, the students as a class came up with this causal loop diagram to explain their understanding of fairy tales:



The more the character is able to achieve his goals, the happier he is. The happier he is, the more he is able to achieve. This was a good discussion.

SAMPLE LESSON: How Life Changed for Native American Tribes

Curriculum: Social Studies/Language Arts. Students study Native American tribes as a beginning to their exploration of the colonization and revolutionary phases of US history.

Background: These two lessons are part of a larger unit on Native Americans and they require that students have some knowledge of Native American history and culture. For example, these students would have each written a research report on one tribe, along with other classroom activities.

Lesson 1, Native Americans

Objectives: Students will gain an understanding and respect for the cultures that existed prior to European arrival on this continent. Children will identify the changes in the Native American way of life and the causes of those changes as well as the interrelationships among factors causing those changes.

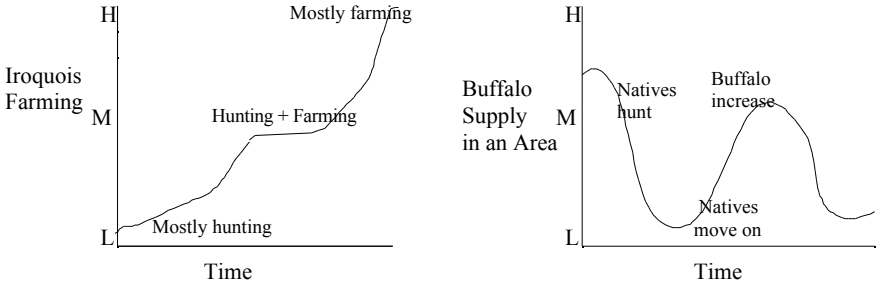
Materials: Paper/pencils; Videotape: *People of the Desert*, *People of the Forest*, *People of the Northwest*, *People of the Plains* (Rainbow Educational Media, Raleigh, NC, 800-331-4047) or any other video or activity that helps students bring together all that they have learned about Native Americans.

Time Required: This activity takes 45 minutes to 1 hour.

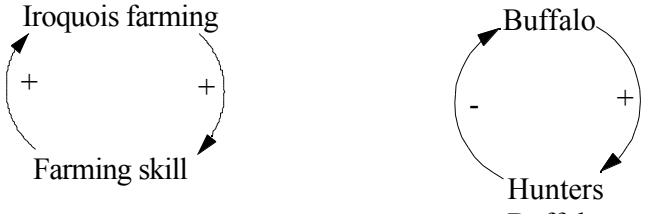
Activity:
First, activate prior knowledge by having children remember their previous learning experiences related to Native Americans and their ways of life.

- Write these graphing reminders on the board: What changed? How did it change? Why did it change?
- Instruct children to think about the way that Native Americans' lives changed over time and jot down any ideas that come to mind. (What changed?)
- Instruct them to watch the video while looking and listening for more examples of things that changed over a broad period of time (trends) as well as remember things that may have changed for the tribe on which they wrote the report. Examples:
    - Number of buffalo killed /year (by Europeans/Americans or by Native Americans)
    - Friendship between Europeans and Native Americans
    - Native American population, populations of specific tribes
    - Anasazi houses as defense structures
    - Food supply
    - Size of war parties
    - War-like behavior of certain tribes (Apaches)
    - Complexity of houses of Native Americans living in the desert
    - Freedom of the Pomo Indians
    - Amount of farming compared to amount of hunting/gathering

- Ask students to select one important change and graph the way it changed. (How did it change?) You may want to demonstrate by graphing several non-related trends with them first. (Sometimes when you do this, some kids tend to copy the demonstration graph even though it does not reflect the change they are graphing. Help them to be sure that their graphs actually say what they want them to say.) Student examples:



- Have students explain the change represented on their graphs to the members of their group. (Why did it change? Why is it important?) "At first the Iroquois were hunters. For a while they did both hunting and farming but as they got better at farming they did more farming." "Hunters would go to a place where there were a lot of buffalo and hunt them until there weren't many left. Then the hunters moved to another place and the buffalo could grow back."
- Have students share their graphs with the class with all students listening for things that might have a relationship with each other. (What are the relationships?) Identify a few changes that might have a causal relationship.
- Draw a causal loop diagram of one relationship.
    - Explain that causal loops are just one more way we can show our learning.
    - As a class, draw a causal loop showing that relationship on the board. Explain the causality while drawing the picture: more of one variable _ more of another (+ sign), or more of one variable _ less of the other (- sign). Every arrow represents a cause; a change in one thing causes a change in the other.
    - If the change builds on itself, it is called a reinforcing loop. That means that once the change gets started, it will continue to grow (or decline), reinforcing itself. In a balancing loop, the change levels itself, restoring a balance.



(The more the Iroquois farm the land, the more skilled they become, and the more they continue farming. This is a reinforcing loop.
The more buffalo in an area, the more hunters come; the more hunters, the fewer buffalo survive. But with fewer buffalo, the hunters leave, allowing the buffalo herd to increase again. This loop is balancing.)

Lesson 2, Native Americans

Objective: Students will create causal loops and understand the connection between causal loops and behavior-over-time graphs.

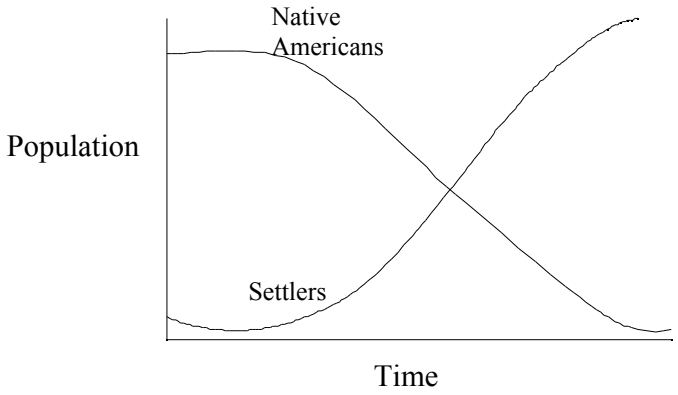
Time required: This activity takes 45 minutes to 1 hour.

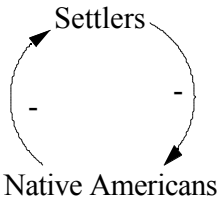
Materials: pencil/paper

Background: Students will use the graphs they created in the last lesson. Review the graphs with them and discuss common errors. (The most common was drawing a graphing pattern which did not reflect what they believed, or said they believed, had happened. This skill comes with practice.) Remind students to evaluate their graphs and make sure they say what they want them to say. Also, review the causal loop diagrams done as a class in the last lesson.

Activity:
Demonstration:

- Make a graph of European/American population and Native American population on the same graph.
- Ask students to explain what the graph says: as European/American population goes up, Native American population goes down.
- Draw a causal loop related to that graph.

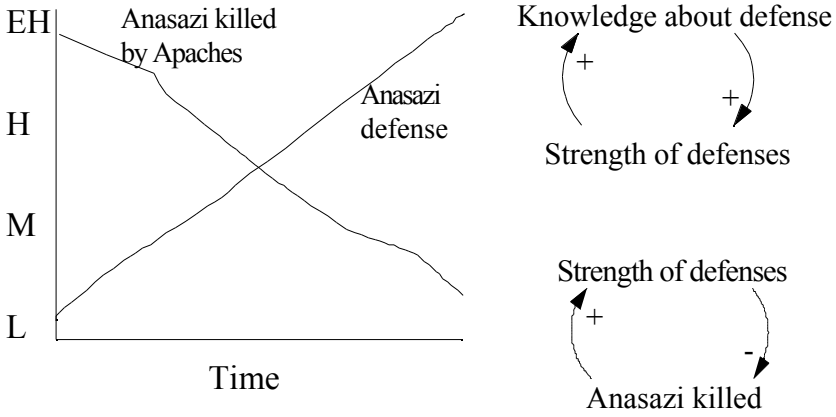




(The more settlers there are in an area, the fewer Native Americans can live there as Natives are killed off or forced to leave. As the Natives decrease, more settlers move in, forcing more Natives out and allowing even more settlers to move in. And so on. This is a reinforcing loop; the number of settlers spirals up while the Natives spiral down. This one is confusing because both signs are negative. An increase in one causes a decrease in the other for both relationships, but their combined effect is reinforcing. Students would need help with this.)

Student activity:

- Ask students to use their own graphs to look for relationships between variables within the Native American experience over time.
- Share the loops as a class, testing to verify causality and identifying balancing or reinforcing loops.
- This is one example by a fifth grade boy who noticed that over time the Anasazi cliff dwellers improved the construction of their houses as defense structures. The more they knew about defense, the better it got. With each innovation, they learned something during an attack to improve the structure even more for next time. As a result, the Apache attackers killed fewer Anasazi people over time.
  (Note that he created his own vertical scale to include "Extra-high." He also illustrated his graph to show the increasing complexity of the houses. This student who often needed help with other assignments definitely "got" this! He did a wonderful job.)



Note about Causal Loops:
Drawing causal loop diagrams seems to be more difficult for these children than drawing behavior over time graphs. We have shown you only the best examples. Although not all of the students' drawings were good causal loops at first, they did all provoke good discussion and a much deeper understanding of what causes change. Their loops are improving as we keep discussing them.

Probably the best advice at this level for causal loop diagrams is to draw them when the causal relationships are obvious to you. Some causal loops just pop to mind during graphing or class discussions. Explore these in depth and spotting other causal relationships will become easier. It is skill which takes practice and which becomes more developed as students learn more about stocks and flows and computer modeling. Asking beginning students to find a loop for every graph may be confusing to them until they develop that skill. Incorrect loops do yield valuable lessons from which students can learn, but if the exercise feels contrived, stick to the obvious ones and build from there.

SAMPLE LESSON: The Causes of the American Revolution

Curriculum: Social Studies. As part of their study of the American Revolution, students learn about the series of conflicts between the colonists and the British that eventually led to war.

Objectives: Students will learn that the American Revolution was not caused by events themselves but by the underlying interdependent changes which caused those events. Students will be able to identify those changes and graph them.

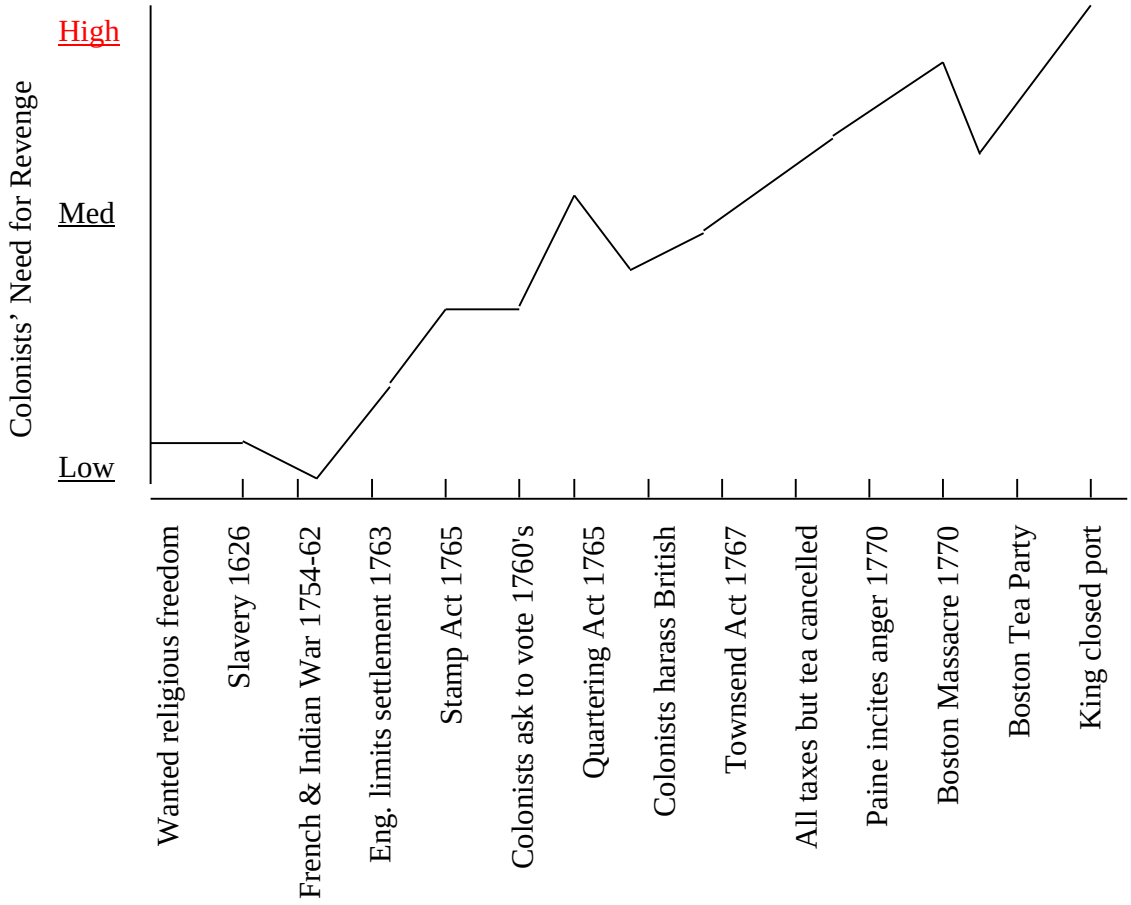
Time required: This one activity takes 45 minutes to one hour, plus an additional 30 minutes for the writing assignment.

Materials: pencil/paper, chalk/blackboard

Activity:
First review with the children what they have learned about the events leading up to the American Revolution. On the blackboard, label the horizontal time axis of a very large behavior over time graph with the events they have studied. Start with the earliest event at the vertex and add events in order as time progresses along the line. (As you do this, students will see that, from the very beginning, the British tried to tighten their grip and the colonists resisted. This went back and forth until fighting finally erupted.)

- What is changing? Ask students to think about what was changing during this time. Encourage them to go beyond just listing events to thinking about what was building up or decreasing with time. For this lesson, this first question generated the most heated discussion. The students could see that tensions were escalating, but it took them a while to identify just what was driving the change. Finally, they settled on the "need for revenge." (We might not call it that, but this term was very meaningful to these kids; they could identify with it and understand the story at their own level.)
- How is it changing? Graph the colonists' "need for revenge" on the blackboard graph (or use whatever variable your class defines instead.)
    - The "colonists' need for revenge" is on the vertical axis with a scale of "low, medium, high."
    - Starting at the earliest event, ask students to decide how high the need for revenge was at that time and plot that point. Do the same for each successive event until you have completed the line graph.
    - Essentially, the colonists' need for revenge goes up when the British impose an unpopular law, it goes down a little when the colonists respond to that law, but it goes up again with another British action, and so on.
- Why is it changing? Students get into this discussion. As one side retaliates against the other, the need for revenge keeps rising. The pattern of behavior is the same for the British. (Relationships?) A graph of the British "need for revenge" would be very similar.

- Why is it important? Continuing their discussion, these students came to the conclusion that getting satisfaction for revenge doesn't always make you happy; you just want more revenge. (How about that for depth of understanding! Remember that these are tomorrow's decision-makers.)
- Using the graph, ask students when they could have stepped in to change things. Could they have averted the war?

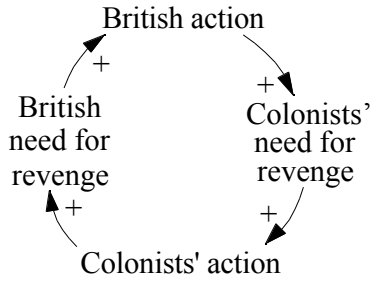


Assignment:

Examine the graph that we created about the colonists' need for revenge against the British. Select two events that could have been handled differently by the British and/or the Americans. Then write a brief explanation including the following:

1. The name of the event and what happened.
2. How it might have been handled differently by the British or the colonists.
3. What the results would have been.
4. How the United States would be different today.

5. Causal loop diagram



This diagram is more advanced than these students could draw. It is just an illustration of how behavior over time graphs and causal loop diagrams can surface very common patterns of behavior. In this case, whenever the British imposed a restriction, the colonists were provoked into action, which in turn provoked the British to respond with another action. (Remember, "revenge" is the fifth graders' term; others might define it differently.) This escalation continued until war broke out. This pattern is prevalent around us. It certainly drives any arms build-up or rising conflict as each side tries to outdo the other. It fuels gang violence. It might even describe many playground squabbles. More advanced students could identify this and build a simple system dynamics computer model to explore the system further.

Don't Stop Now!

Behavior-over-time graphs teach students to look for patterns of change over time and the relationships that cause them. They engage students in lively discussions and deeper thinking. They are easy to use if you follow the questions:

- What is changing? (Identify the variables.)
- How is it changing? (Draw the graphs. Examine the patterns.)
- Why is it changing? (Look for causal relationships.)

Behavior-over-time graphs also underlie the understanding and practice of system dynamics. System dynamics starts with these same questions. However, it goes beyond the classroom discussions above to make all assumptions very clear and consistent, and to test those assumptions on a computer simulation. In the process, students gain an even deeper understanding of the behavior, what is causing the change, and how they can influence it.

Use behavior-over-time graphs often with your students across all age levels and curriculum areas. They are a great classroom tool all by themselves. But they do more. They teach students to think more deeply about the change that surrounds them. And they prepare students to use the other system dynamics tools to deepen that understanding even further.

Feedback

We welcome your suggestions and comments on these lessons. Please send them to us via the Creative Learning Exchange. Thanks.