The Infection Game:
The Shape of Change

The text of
Lesson 5: The Infection Game
From the books

The Shape of Change
and
The Shape of Change: Stocks and Flows

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Illustrated by Nathan Walker
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The Shape of Change

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Introduction

Students play a game that simulates the spread of an epidemic. The behavior we see in the game could represent bacteria spreading through an animal population, a virus spreading through a computer network, a rumor spreading through a school, the adoption of a fad in a country, or any other type of contagious agent.[1]

Social studies concepts could include the spread of disease in the New World, and the spread of ideas, social movements, or revolutions. The spread of disease can also be discussed from the science point of view. The disease in question might be a cold virus, the flu, smallpox, or AIDS. Math skills include drawing and interpreting graphs, fitting a curve through data, and looking at patterns of behavior over time.

Combine two classes to play this game. It takes at least 35 players to generate clear patterns of behavior.

Materials

Copies of four student worksheets:

1. *Individual Record Sheet A*, for *one* student (page 11)
2. *Individual Record Sheet B*, for all remaining students (page 12)
3. *Spread It Around*, for each student (page 13)
4. *Spread It Around Again*, for each student (page 14)

One copy of the *Teacher's Class Record Sheet* (page 15)

How It Works

In this game the interaction that drives the spread of an epidemic is represented by the multiplication of numbers. One student will be assigned the number zero, while the rest will be assigned the number one. As they multiply their numbers together in pairs, the repeated multiplication process will cause more and more products to result in zero. In other words, the number zero simulates the infective agent spreading through the population.

Do not divulge this background information to students. Their motivation and learning is much more effective when they discover the structure for themselves.

Generic Structures

A similar pattern in different situations is called a *generic structure*. This game simulates the generic structure of the spread of contagious activity, or infection. Once students understand the spread of an epidemic, they also understand the spread of a rumor, a fad, a social movement, or a computer virus, for example. The basic structure is the same.

Procedure

1. Explain the rules without telling students the name of the game.

Infection Game Rules

1. You will each receive a sheet to track the results of the game.
2. You will each be given a secret number which will be already filled in on your record sheet.
3. Secrecy is very important to this game.
4. You will play the game for several rounds. In the first round, find any other student, and quietly tell each other your numbers. Then, on your own, secretly multiply your two numbers together and record the product on the next line of your sheet. This will be your new number for the next round.
5. Example: If you have a 2 and the other student has a 3, you will both get 2 X 3 = 6 for your new number on the next line.
6. Second round: Find any other student, exchange numbers, secretly multiply them together, and record the new product for the next round.
7. Continue to do this until the teacher ends the game.

Note: By using the numbers 2 and 3, instead of 0 and 1, you deliberately mislead the students a little. This adds to the surprise element.

2. Give one ***unknowing*** student *Individual Record Sheet A* (page 11) and give the rest of the students *Individual Record Sheet B* (page 12). Re-emphasize the importance of secrecy, and let students play the game for about 4 minutes

- Give the sheet with the starting number 0 to a student who is reliable about following directions and who is likely to exchange numbers with a variety of boys and girls.
- You do not need to interrupt play to announce rounds. It works best if you just let students mingle freely for about 4 minutes.

3. When time is up, ask students to notice the last product on their sheets. Most, if not all of the students should have the number zero. Ask who *started* with the number zero. Tell students that they will be asked to think about this later.

4. Gather data from the students now for later debriefing.

- Ask students who had their FIRST entry of zero in the beginning to raise their hands. (This should be only *one* student.) Record this information on the first column of the *Teacher's Class Record Sheet* (page 15).
- Ask for hands to count how many students had their FIRST entry of zero in the second round. Repeat this for all subsequent rounds and record the information until there are no new "infections" with zero. Do not discuss or reveal the results to students yet.
- It is essential to record *only* the number of *new* students infected each round in the first column.
- You will also need the *total* number of infected students as the game progressed. Record this in the second column of the *Teacher's Class Record Sheet*, by keeping a running tally and adding the number of new students each round, as below.
- (You do not need to be overly concerned about accuracy in counting. Small errors will not affect the overall outcome.)

Round	Number of **NEW** Zeros	**TOTAL** Number Of Zeros
Start	1	1
1	1	2
2	2	4
3	4	8
4		

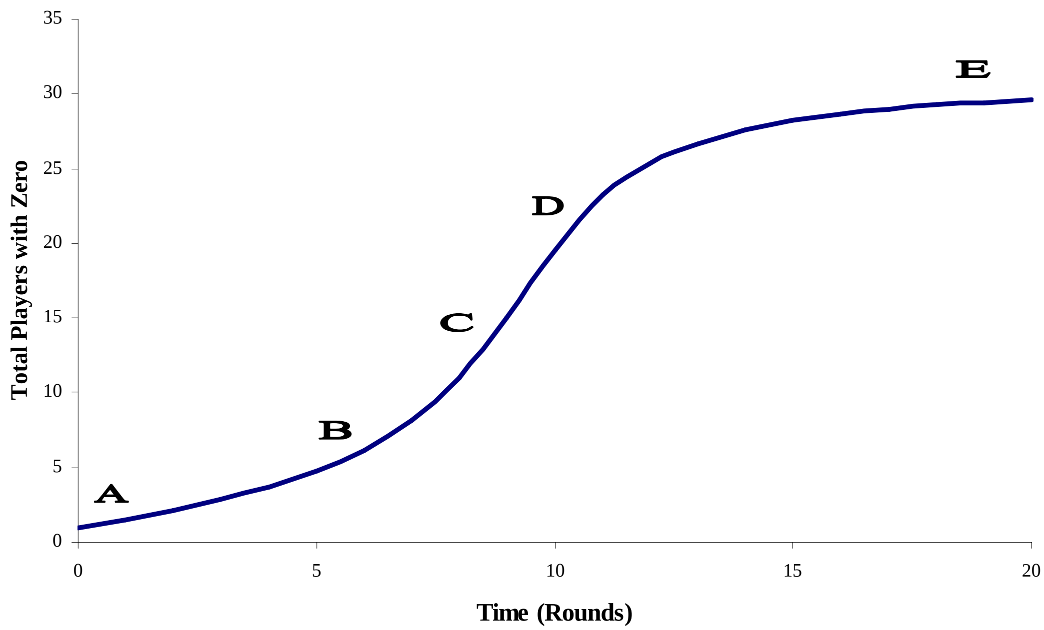
5. Provide some individual reflection time for students to think about the *total* number of students with a product of zero as the game progressed. *Without revealing the actual data*, ask students to draw *behavior over time graphs* representing what they think happened to the *total* number of students with a product of zero during the game using the worksheet, *Spread It Around* (page 13).

> A ***behavior over time graph*** is a line graph sketch showing how the number of infections changed over time during the game. It reveals a pattern of behavior.

6. Students share their predictions with their teammates, reach a consensus and draw the team graphs on their worksheets.

- Ask each team to send a representative to the board to sketch the team's graph and explain the reasoning behind it.
- At this point, it is more important for students to explain their thinking than to produce the "correct" graph.

7. Compare the student predictions with a graph of the actual results of the game. Using data previously collected on the *Teacher's Class Record Sheet*, use the values in the Total Number of Zeros column to plot a graph on the board as a class.



It is important to focus on the general pattern of behavior, rather than on the details. Your graph will be different from our example below, but the general shape should be similar.

Bringing the Lesson Home

Use the graph to help students understand the progress of the "infection" and its real–world implications. Devote ample time to this very important step so that students can use their experience to construct a deeper understanding of the world around them. .

? **What does the graph tell us? What happened to the number of students "infected" with zero during the game?**

At first only one student was infected, but the infection eventually spread to everyone in the class in a general pattern called "S-shaped growth."

? **How is this graph different from the team prediction graphs? How is it similar?**

By evaluating their earlier predictions, students reflect on their own thinking.

? **Why does the line have an S shape? How does this relate to what was happening during the game?**

Engage students in a dialogue about the shape of the graph and relate the different sections of the graph to different phases in the game. If the students have difficulties, ask questions rather than giving them answers to get them to think about the different phases.

? **What was happening at region A in the graph? Why is the line flatter?**

This is the initial spread. Very few people had the infection, so it spread very slowly at first.

? **What was happening at region B? Why is the line steeper?**

Growth was increasing. As more and more people were infected and they interacted with others, the disease spread at an increasing rate.

? **What happened at C? Does the curve change its shape?**

At this point the curve changes its direction, like an "S."

? **What was happening at region D?**

Now growth was decreasing. When most people already had the illness, there were fewer healthy people to infect, so the disease spread more slowly. The number of infected people was still increasing, but at a slower rate.

? **What was happening at region E? Why is the line flat?**

There was no further growth. Everyone was infected.

Now, broaden the lesson with questions like these.

? **How is this like something else we are studying?**

Explore links to the curriculum. For example, if the game is played in a history class, ask students to predict the effect of Europeans carrying the smallpox virus when they had contact with native people in the Americas. If the game is part of a general economics curriculum, ask students to list some fads or products that spread rapidly through society.

? **Can students think of other examples of this infection behavior? Without intervention, the "infection" starts out slowly and spreads more rapidly until it approaches saturation.**

- *Other infectious diseases like the flu or medical problems like head lice*
- *Rumors spreading through a school*
- *Computer viruses*
- *A fad like a style of clothing, a new toy, a popular song or movie.*
- *The adoption of a new technology like cell phones or DVD players.*
- *A social movement or political idea like the American Revolution, abolition of slavery, or women's suffrage*

? **In what way is this simulation NOT realistic? What are limitations of the simulation?**

This simulation shows a disease from which there is no recovery. That is, once you are infected, it is not possible to revert back to "uninfected." In the real world this almost never happens. Usually there are some individuals who recover. Other individuals might be resistant and do not get the disease at all. Depending on the ability of the students, you might ask them how the rules of the game would need to change to make the game more realistic.

The simulation also implies that contact with a carrier will always result in getting the disease. Again this is highly unlikely – the probability that a contact will result in actual infection is almost always less than 100%.

While it is possible to change the rules of the game to reflect these issues, it is interesting to note that doing so will not significantly alter the shapes of the graphs.

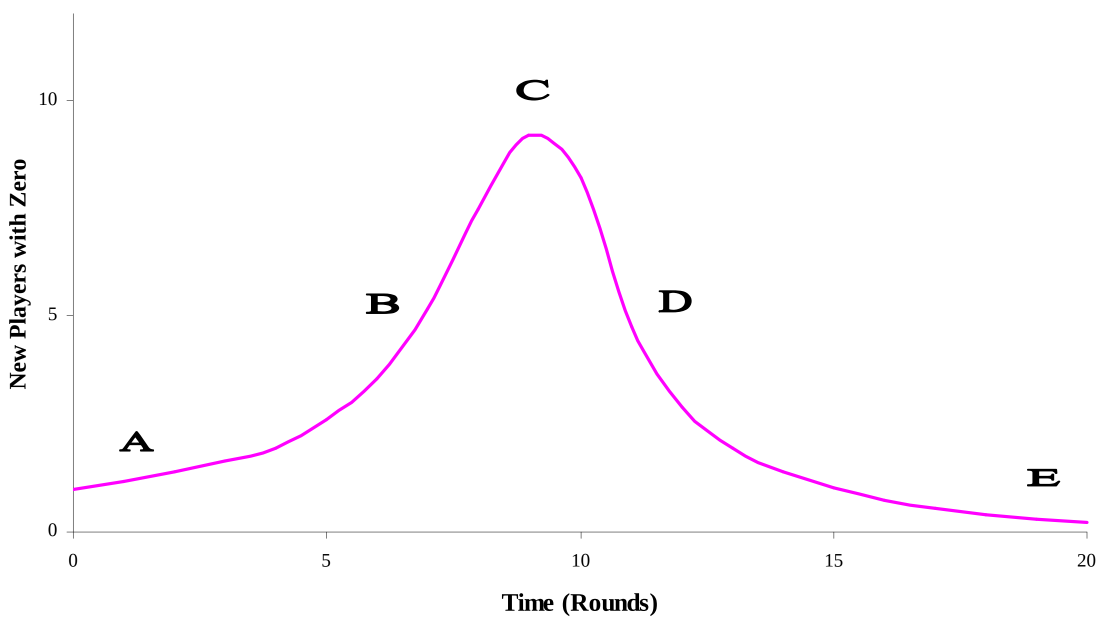
> The game is a simplified version of reality. By simplifying reality, it is easier to understand the "structure" of reality. However, it is important to keep in mind that the game includes a number of assumptions that make it different from real life.

Take Another Look

It is also interesting to explore the *rate* of the spread of the infection. In student terms, how many *new* people are infected in each round (rather than the *total* number of people infected)?

Students can now analyze the data of the number of *new infections* each round. Lead a discussion similar to the debriefing of "the *total* number of students with a zero", but this time focus on "*new* students with a product of zero."

- As before, ask students to draw *behavior over time graphs* of what they think happened to the number of *new* infections over the course of the game using the worksheet, *Spread It Around Again* (page 14).
- After discussing their predictions, use the teacher's data for the "Number of New Zeros" to draw and analyze the actual graph of the game. Again, the class graph may differ somewhat from our example below, but the general shape should be similar.
- Focus on the general pattern of behavior, not the details.
- Carefully lead a dialogue to elicit student understanding.



? **What happened to the number of new infections?**

There were only a few new infections at first. Then there were many. By the end there were no new infections. This pattern is called a "bell-shaped" curve.

? **How is this graph different from the team predictions? How is it similar?**

? **What does the shape of the curve say about what was happening in the game?**

As before, ask questions to elicit understanding of the phases of the game.

? **What was happening at region A?**

The infection started off slowly, but then grew at an increasing rate as more and more people transmitted the infection.

? **What was happening at region B? Why is the shape of the curve changing?**

When fewer contacts resulted in new infections, the number of new infections slowed down, but it was still increasing.

? **What happened at C?**

The number of new infections reached its peak. This corresponds to point C on the previous graph where the line changed direction like an "S." (All of the letters on the graphs correspond. This point is particularly noteworthy because it is a turning point.)

? **What was happening at region D?**

The number of new infections was declining. The total number of infections was still increasing, just at a slower rate.

? **What was happening at region E?**

There were no new infections because everyone was already infected. The epidemic had run its course.

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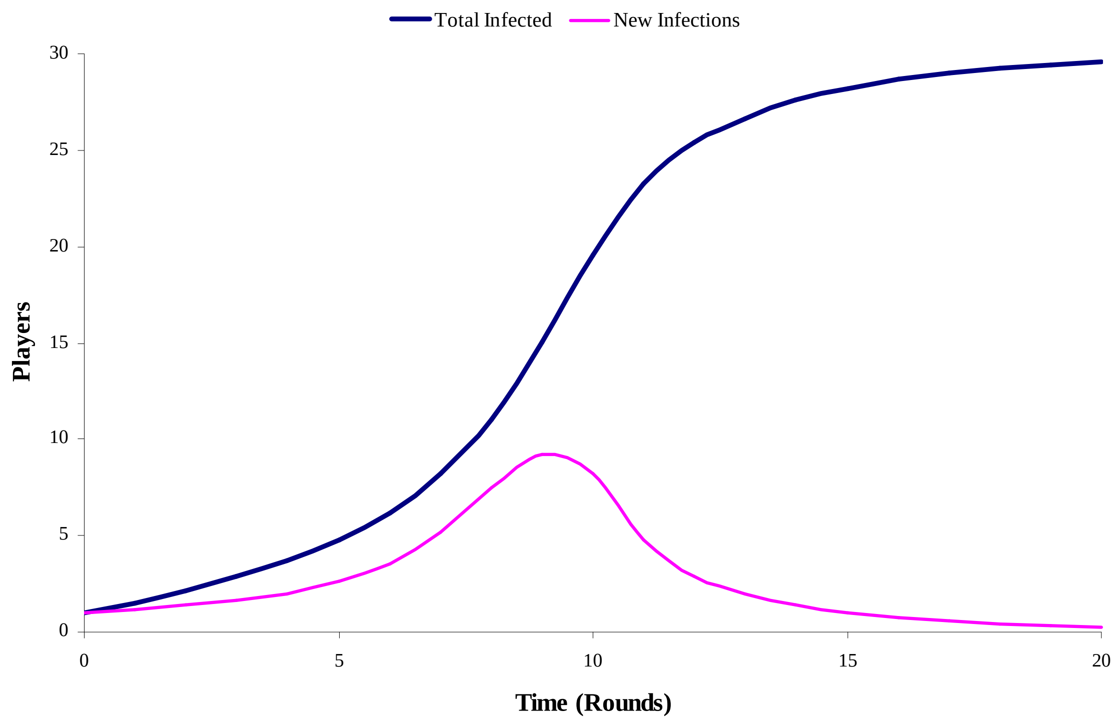
Stocks and Flows

The *total* number of infected students is a **stock**, or an accumulation over time. It is increased by the number of *new* infections that **flow** in each round.

? **How does the graph of the *new* infections relate to the graph of *total* infections? If these graphs are drawn on the same time scale, what will they look like?**



The rate of new infections starts off slowly, but increases at an increasing rate. When the rate reaches its maximum (top of bell curve), the total number of infections continues to increase, but at a slower rate. So, while the number of NEW infections is DECREASING, the TOTAL number of infections is still INCREASING. At the point when the number of new infections is zero, the total number of infections has reached its maximum – everyone is infected.

? **How does this pattern relate to the other curriculum and real world examples of "infections" discussed earlier?**

As before, discuss the spread of other diseases, rumors, computer viruses, fads, social movements and other contagions suggested by students,

Notes

[1] The Infection Game is adapted from the Epidemic Game developed by Will Glass at the Catalina Foothills School District, Tucson, Arizona, 1993. The "Epidemics Game Packet" includes the original game, a system dynamics model and student exercises for older students. It is available from the Creative Learning Exchange at www.clexchange.org

Thanks to Jan Mons of the GIST Project in Brunswick, Georgia for her suggestions.

Name___________________

Individual Record Sheet

Form A

1. You start out with a number given to you by the teacher (the number is written next to Start below). *Do not share this number with anybody, except as explained below*.

2. Once the game starts, select another student and exchange numbers. On your own, secretly MULTIPLY the two numbers and write the product on the next line. Now this is your new number.

3. Select another student and repeat the process until time is called.

ROUND	**NUMBER**
Start	___0____
1	________
2	________
3	________
4	________
5	________
6	________
7	________
8	________
9	________
10	________
11	________
12	________
13	________
14	________
15	________
16	________
17	________
18	________
19	________
20	________

Name__________________

Individual Record Sheet

Form B

1. You start out with a number given to you by the teacher (the number is written next to Start below). *Do not share this number with anybody, except as explained below*.

2. Once the game starts, select another student and exchange numbers. On your own, secretly MULTIPLY the two numbers and write the product on the next line. Now this is your new number.

3. Select another student and repeat the process until time is called.

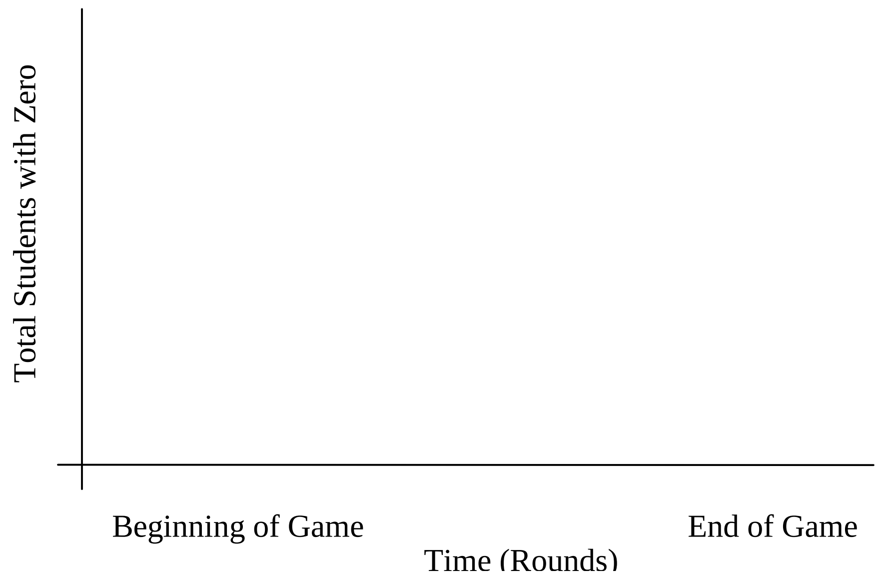
ROUND	**NUMBER**
Start	___1____
1	________
2	________
3	________
4	________
5	________
6	________
7	________
8	________
9	________
10	________
11	________
12	________
13	________
14	________
15	________
16	________
17	________
18	________
19	________
20	________

Name__________________

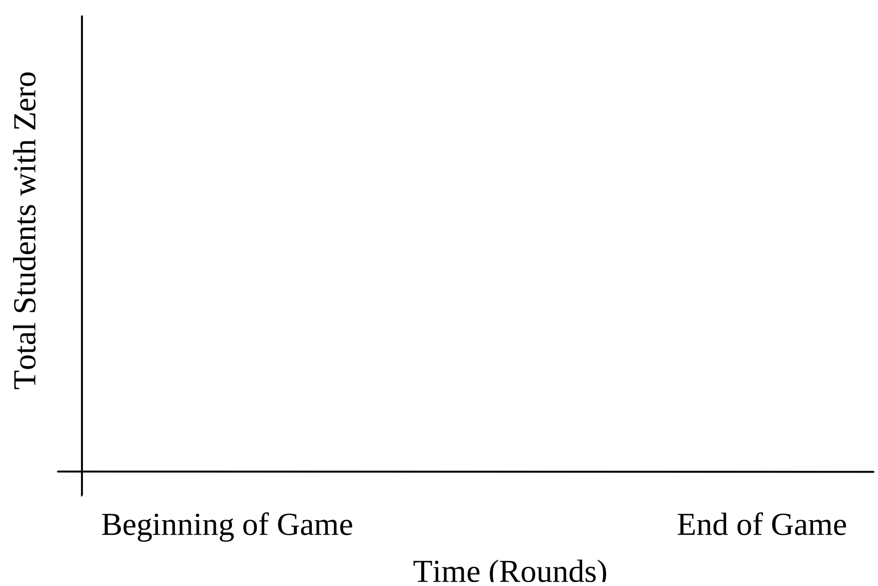
Spread It Around

Total Students with Zero

1. Sketch what you think happened to the *total* number of students who had a product of zero as the game progressed.



2. Compare your graph with the graphs of your teammates. Explain your thinking to your teammates and listen carefully to their explanations. Come to an agreement with your teammates and sketch your team's graph below. Be prepared to explain your thinking to the class.

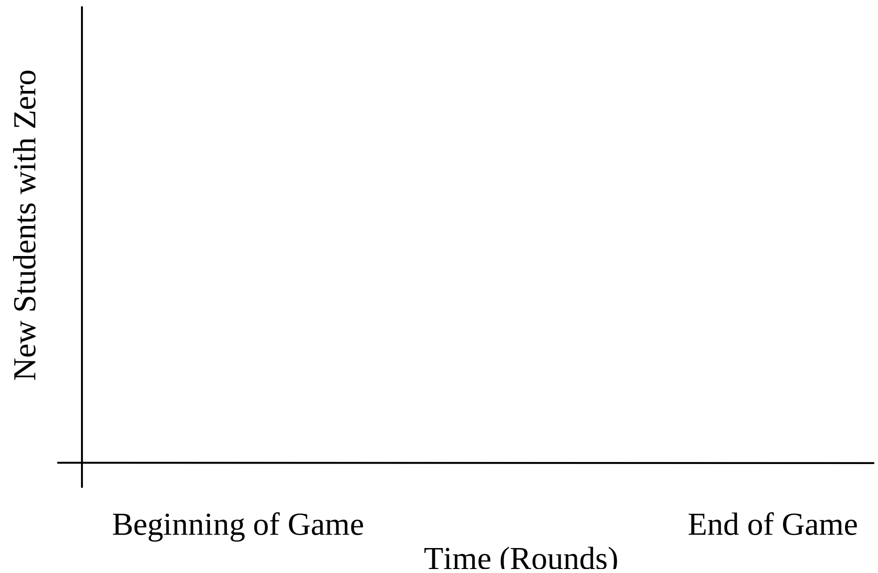


Name________________

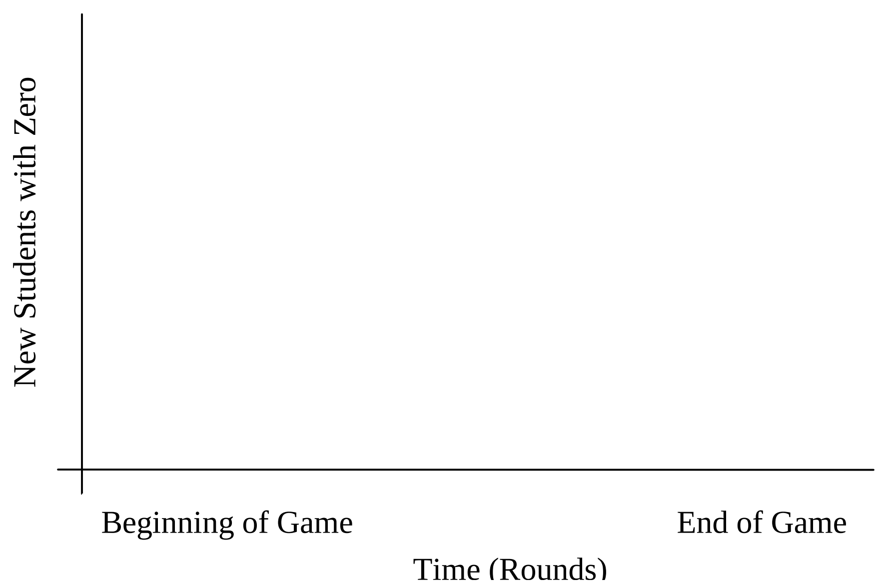
Spread It Around Again

New Students with Zero Each Round

1. Sketch what you think happened to the number of students *newly infected* each round as the game progressed.



2. Compare your graph with the graphs of your teammates. Explain your thinking to your teammates and listen carefully to their explanations. Come to an agreement with your teammates and sketch your team's graph below. Be prepared to explain your thinking to the class.



Teacher's Class Record Sheet

The Infection Game

Round	Number of **NEW** Zeros	**TOTAL** Number Of Zeros
Start		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

*All of the lessons in **The Shape of Change, Stocks and Flows** build directly on classroom activities and lessons presented in **The Shape of Change**, also by Quaden, Ticotsky and Lyneis (2004), available from The Creative Learning Exchange. These lessons also build on one another sequentially.*

The Shape of Change

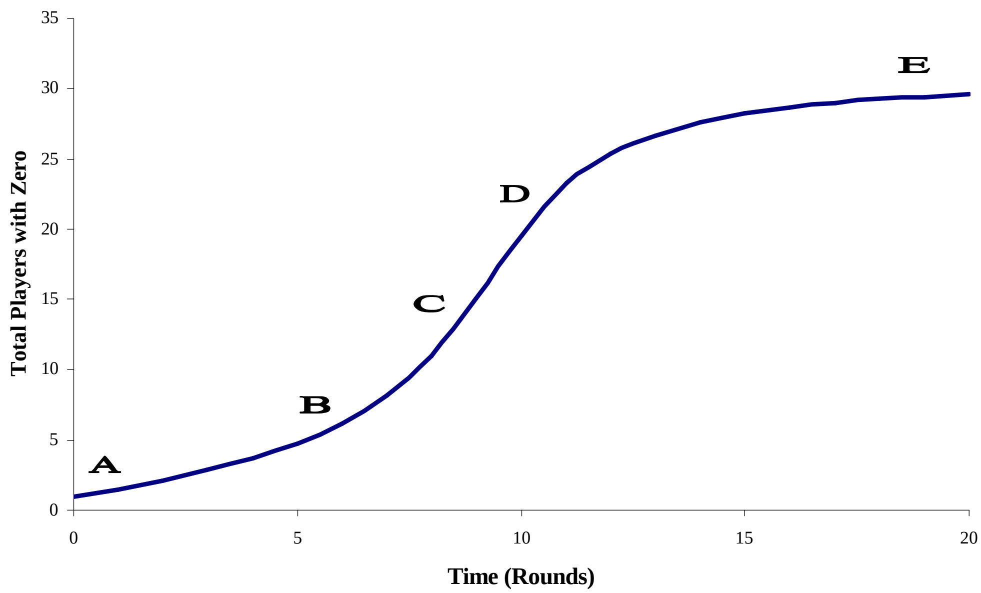
In Lesson 4 of ***The Shape of Change***, students played a game to simulate the spread of an infection. As they multiplied their secret numbers together, the infection (the number zero) spread through the class in a pattern of S-shaped growth. See Pages 51-64 in ***The Shape of Change*** for the complete lesson.

Overview

The Infection Game stock/flow map combines all the elements that were used in the previous lessons. Students apply all that they have learned about behavior over time graphs, stocks and flows, and reinforcing and balancing feedback loops to understand how and why the infection spread among them. There are two stocks and two feedback loops in this simulation.

Seeing the Structure

1. Review the Infection Game graph of the total number of players with zero. Briefly discuss what happened in the game to produce this behavior.

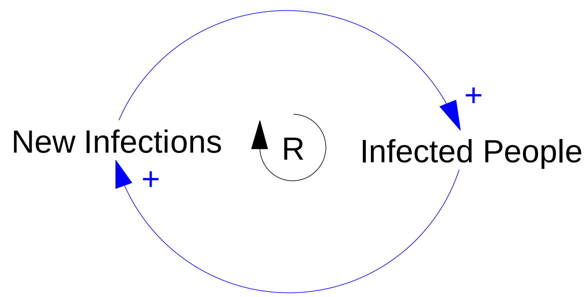


Look closely at the graph for hints about what structure could be causing the behavior you observed.

At first (point A) few people were infected with zero, but as more people became infected and they infected others, the rate of infection increased (point B). Eventually, the rate of infection slowed (point D) because many people were already infected. Eventually everyone was infected (point E).

2. Notice that the first section of the graph (at points A and B) is like the upward curving exponential growth graphs we saw for Making Friends and the Mammoth Game births. As each friend chose a new friend, more new friends led to more friends on the team, which led to even more new friends, and so on. Mammoth births led to even more births. These were examples of positive feedback loops.

   Think about what happened in the Infection Game. At first only one person was infected, but as more people had zero, the infection spread more and more quickly. More infections led to even more infections. A **reinforcing feedback loop** must be at work here too, causing the **exponential growth** we see in the graph at the beginning of the game. Maybe a loop like this one was causing the growth:

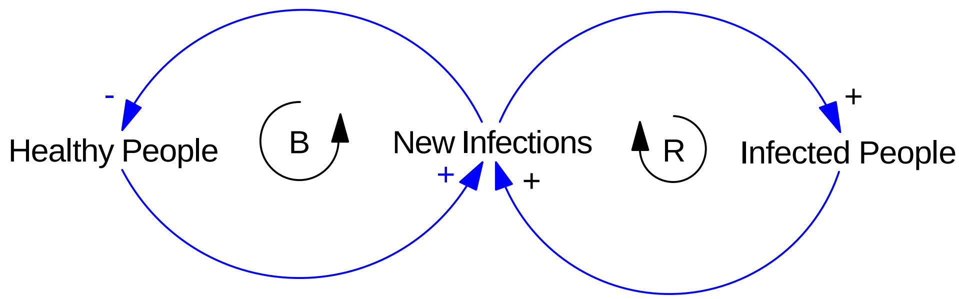


3. Now take a look at the next segment of the graph (starting at point C). Notice that the growth is slowing as the number of infected people approaches the total number of players in the game. As more people became infected, there were fewer and fewer healthy people left to infect, until finally everyone was infected (at point E).

   The growth in the number of infections in this graph segment appears to be *approaching a goal*, similar to the pattern of ice water warming up to room temperature caused by a balancing feedback loop in Lesson 4. We also saw balancing loops cause decay toward a goal when boiling water cooled to room temperature in Lesson 4 and when mammoths approached extinction in Lesson 3. These balancing loop examples have different stock/flow structures, but they all grow (or decay) quickly at first and level off as they approach a goal.

   Goal-seeking is the distinguishing feature of all balancing loops.

A **balancing loop** must be causing the **leveling off** of the infected population in the Infection Game. Maybe a loop like this one was also at work:



An increase in New Infections caused a decrease in the number of Healthy People. Fewer Healthy People led to fewer New Infections because an infected person was less likely to encounter a healthy person to infect. Healthy People still decreased, but at a slower and slower rate.

Thinking about Feedback Loops

We have studied our graph looking for clues as to what feedback loops could be causing the S-shaped growth we observed in the game. Based on what we have learned in previous lessons about basic feedback loops and stocks and flows, we have hypothesized that a reinforcing loop could be causing the initial growth in infections until a balancing loop takes over to slow the growth, and we have drawn very rough sketches of those feedback loops.

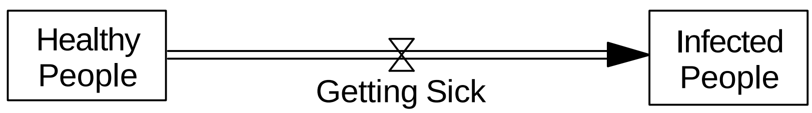
Next, we will construct a stock/flow map to think much more carefully about how this system actually works, why it produces the behavior we observe, and how we could use that understanding to effect change.[1]

That's the general idea. Of course, students will have difficulty recognizing the signs of reinforcing and balancing loops or drawing initial causal loop diagrams until they have practiced with basic structures and their patterns of behavior in a variety of systems.

If your students are not ready to draw these feedback loops at this point, then just discuss the graph in terms of what feedback processes *might* be involved (without drawing causal loop diagrams) and build the stock/flow map to uncover them. The goal is to help students build an intuition about how feedback systems work. With practice, they will deepen their understanding of how the structure of a system creates its behavior.

4. Ask students to identify one or more stocks in the game. Students generally will come up with "Infected People" and "Healthy People."

5. Ask what happened in the game and how to show that on the map. Again, students will have no difficulty seeing that there was a flow of people from Healthy to Infected. They may describe the flow as "people getting sick" or "catching the disease." Draw a flow from one stock **to** the other.

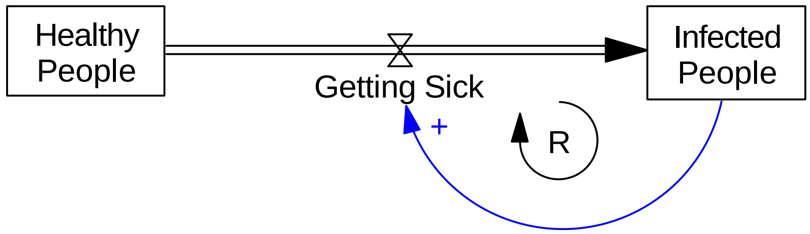


Conserved Flows

We know that stocks can be changed only by flows. In some one-stock models such as the In and Out Game and the Mammoth Game, inflows originate from "cloud" symbols. The source of the flow lies outside the boundary of the stock/flow map. Similarly, outflows often drain into "clouds." When players leave the In and Out Game, or after mammoths die, we no longer track their behavior.

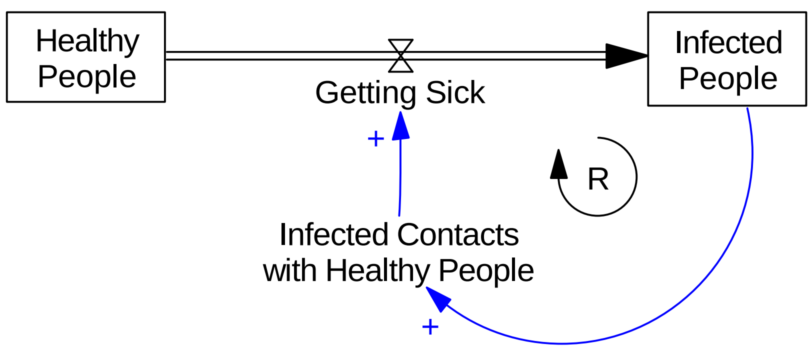
The Infection Game has two stocks, and players move from one to the other during the simulation. The total number of players always remains the same. People in the game are either healthy or infected, but they do not leave the game. The flow that links the stocks conserves the number of players at a constant level.

6. Refer back to our graph of players infected with zero. Let's think first about what could be causing the accelerating growth at the beginning of the game. As more people became infected the rate of getting sick increased. Ask students to think about similarities to the Friendship Game and mammoth births and suggest a structure for the growth in infections.



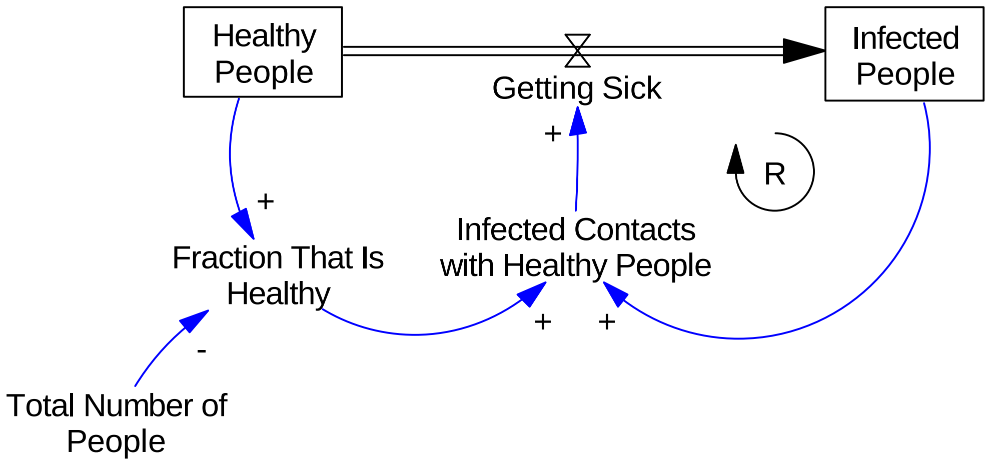
This is a **reinforcing feedback loop**. As more people got sick, there were more infected people, leading to even more people getting sick.

7. However, in the game, this exponential growth did not keep going forever. Refer again to the graph and ask students to relate what happened. As more people got sick, there were fewer and fewer encounters with healthy people to infect. In the end, it was hard for an infected person to find a healthy person at all—everyone was already infected. The rate of Getting Sick depended on an infected person meeting a healthy person.



8. Infected people encountered fewer and fewer healthy people as the game went on. Ask students to think about how and why Infected Contacts with Healthy People changed.

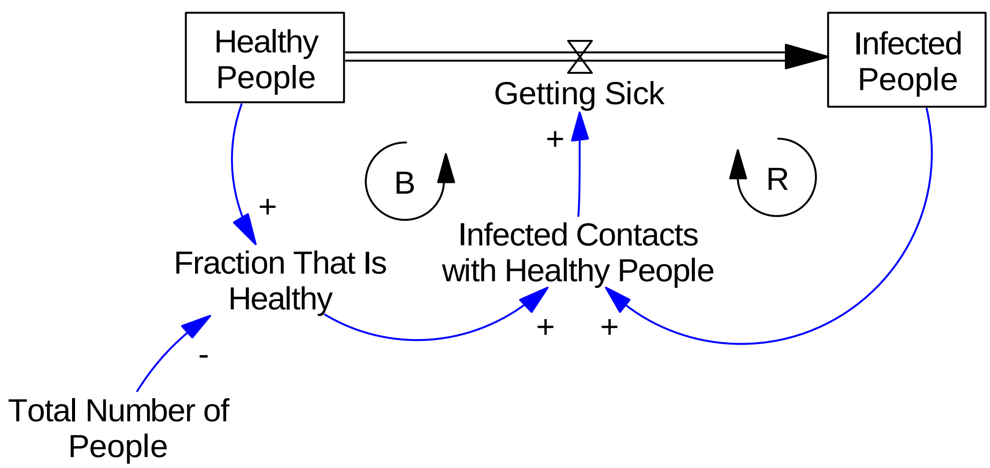
   Think of the game. How likely was it for an infected person to meet a healthy person when nearly everyone was still healthy at first, or when only a few people were still healthy at the end of the game?   Using numbers and assuming there were 50 players in the game, how likely was it when 40 out of 50 were healthy, when 25 out of 50 were healthy, or when only 5 out of 50 were still healthy? The number of Infected Contacts with Healthy People depended on the proportion, or fraction, of the class that was still healthy. When a larger fraction of the class was healthy, the chance of an infected person meeting a healthy person was higher.



The Fraction That Is Healthy is the fraction of the whole class that is still healthy. It is the likelihood that an infected person will meet a healthy person.

9. Ask students to trace this loop and tell its story in terms of the game, using up and down arrows if that helps. As the fraction of the population that is healthy grows smaller, there are fewer infected contacts with healthy people, causing fewer new people to get sick. The rate of Getting Sick slows down. If any people are still getting sick, the number of healthy people is decreasing, but at a slower and slower rate until there are no healthy people left.

   This is a **balancing feedback loop** causing the number of healthy people to approach zero (and, consequently, the number of infected people to approach the total number of people.)

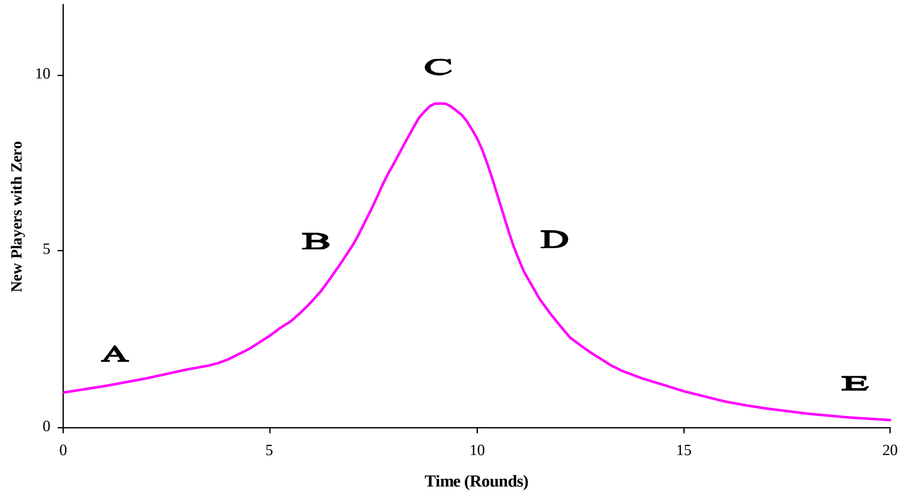


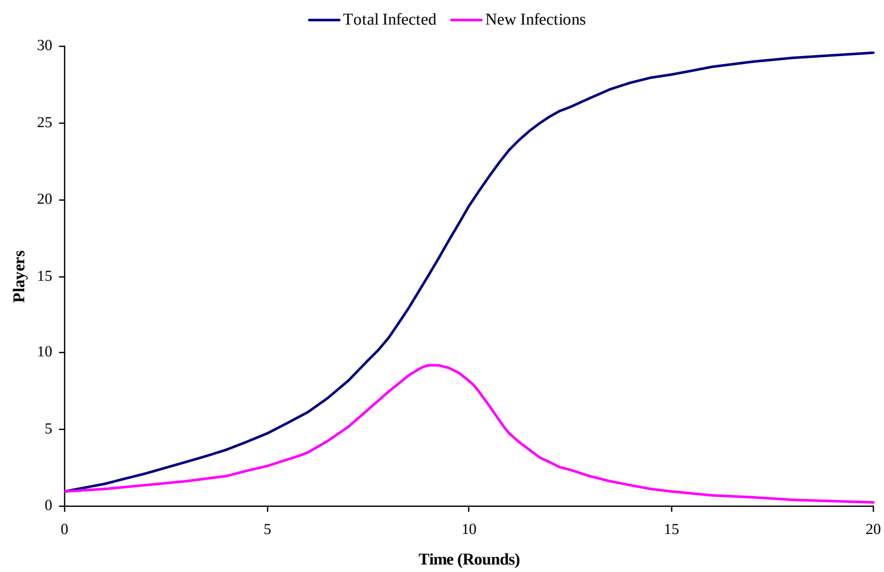
This stock/flow map captures the dynamics of the Infection Game. Its two feedback loops are both necessary and sufficient to explain the S-shaped growth we observed.

? **Two feedback loops caused the infection to spread through the class in a pattern of S-shaped growth. Were both loops active all the time?**

Yes. The reinforcing loop caused healthy people to become infected. This loop was dominant at first because there were plenty of healthy people to infect; the infected population could grow more and more rapidly. The balancing loop limited that growth, but its effect did not dominate until there were fewer and fewer healthy people left to infect. People were still becoming infected, but at a slower and slower rate.

*The shift in dominance from the reinforcing to the balancing loop occurred at point C on our graph. We also saw this on our graphs of new infections in **The Shape of Change** (Pages 57 and 59). (Note: "New Infections" is our flow of "Getting Sick." "Total Infected" is our stock of "Infected People.")*



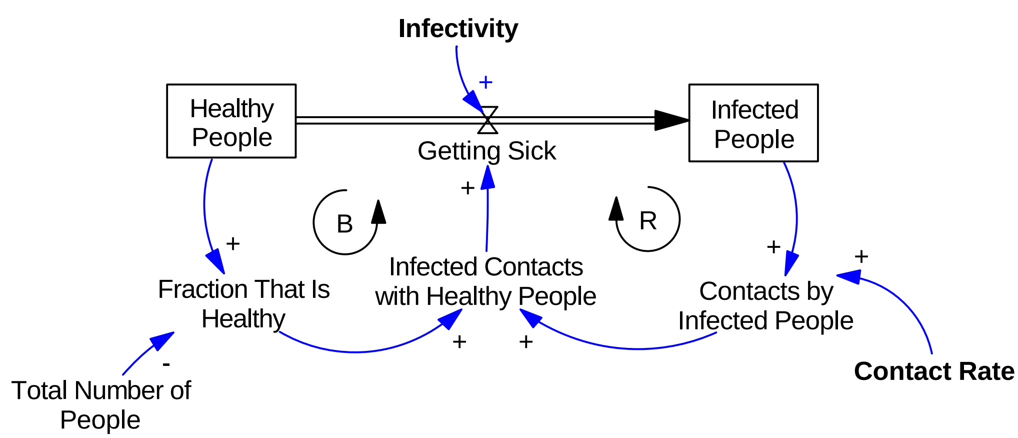


? **Our stock/flow map explains what happened in our Infection Game, but the game and the map are simplifications of real-life epidemics. What else is missing?**

We have made two important simplifying assumptions in the Infection Game.

First, we assumed that every contact of an infected person with a healthy person resulted in transmission of the infection. In the real-world, infectivity is rarely, if ever, 100%. You do not catch a cold every time someone sneezes near you. In reality, only a fraction of exposures result in an infection, with some illnesses being catchier than others. We would show this in our stock flow map by showing that ***Infectivity*** *affects the flow of people getting sick.*

Also, in the game, every person contacted one other person during each round. In the real world, infected people may have different numbers of contacts, depending on whether they stay home or go to school when they are sick, for example. We would show this on our map by adding a ***Contact Rate.***



It is interesting to note that neither of these additions would change the underlying behavior of the system. The reinforcing and balancing loops would still work in the same way to produce S-shaped growth, although the changes would happen more or less quickly depending on the different contact and infectivity rates.

? **What else is missing?**

Students may suggest many other differences between the game and reality. For example, in real-life, some people may recover from an illness while other people may die. People can develop immunities to some illness but not to others. New people may enter the population through births or immigration, for example. There may be delays in incubation times. There might be vaccines or quarantine policies.

Use our basic stock/flow diagram as a springboard to discuss all these issues. However, we do not need to add these complexities to our stock/flow diagram to explain the basic dynamics of an epidemic.

? **Does this remind you of other contagions?**

Students may suggest many different examples including the spread of a computer virus, a fad, a social movement, or a rumor. All of these "infections" have the same basic structure and behavior.

The object of the Infection Game is to understand, in its simplest form, how an epidemic spreads. How do the reinforcing and balancing feedback loops control the behavior? Can we use this understanding to change the system?

[1] Students can gain valuable insights and inquiry skills approaching a problem in this way. For an even more rigorous analysis, the next step would be to build a system dynamics computer simulation of our stock/flow map one loop at a time, see if it can actually generate the graph's behavior, and use it to experiment with policies to change the behavior. But, that is far beyond the scope of this book—a challenge for another day!