The In and Out Game:
The Shape of Change

The text of
Lesson 1: The In and Out Game
From the books

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

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With Debra Lyneis
Illustrated by Nathan Walker
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The Shape of Change

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Introduction

The In and Out Game is a simple activity that introduces and reinforces the understanding of change over time. Players physically move into and out of a designated area of the classroom to observe how the total number of students in the area changes as students enter and leave. By looking at a table and a graph of the action in the game, students learn concepts that will be applied to other activities in this book. The In and Out Game reinforces math skills such as recording, graphing, and predicting.[1]

Materials

Large display area (easel pad, display board, or chalkboard)
Large easel graph pad
Colored markers and chalk
Rope or tape to mark out areas of the classroom floor

How It Works

The number of students in the designated game area changes over time as some players enter the area and other players leave during each round. Students count the total number of players in the area after each round and record their observations on a class graph. In the first game, the rule is: 2 students "In" and 1 student "Out" each round. In the second game, students play with different rules, make predictions and compare the results. They learn through experience that the change in the total number of students in the area depends on the number of students flowing in and out over time.

One way to view the accumulation of players in the area is to think of them as a "stock," like a stock, or quantity, of goods on a store shelf. The stock of goods is increased by restocking and depleted by customer purchases over time. Other changes over time can be viewed in the same way.

- The accumulation of water in a bathtub increases as water flows in through the faucet and decreases as water flows out through the drain.
- Money in a bank account increases with deposits and decreases with withdrawals.
- Populations of people and other species change over time through births and deaths.
- The number of passengers on a bus or train varies as people get on and off.
- Your weight depends on the calories you consume and burn off.

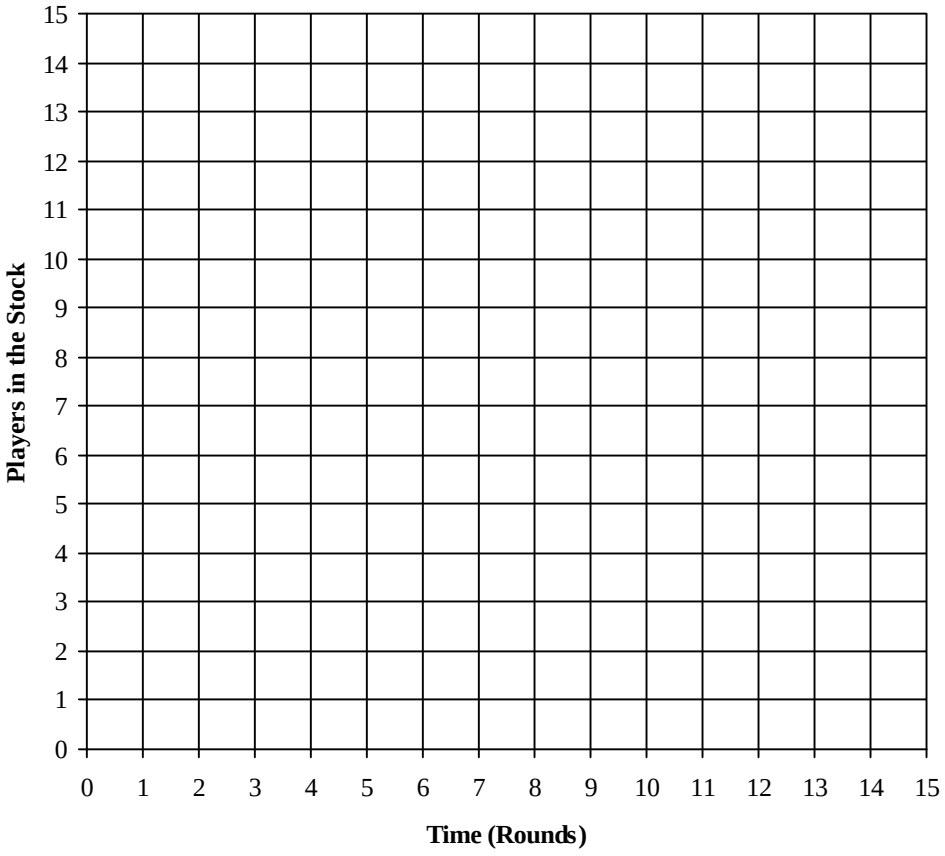
So, if you are wondering why something is changing over time, it is useful to think of it as an accumulation (or stock) and ask what is flowing "In" and "Out" over time to cause the change.

In this game, students are playing with the very basic structure of change as they examine and document what happens to the total number of students in the stock as some students "flow" in and out. Students begin to notice patterns of behavior over time and their causes.

Procedure

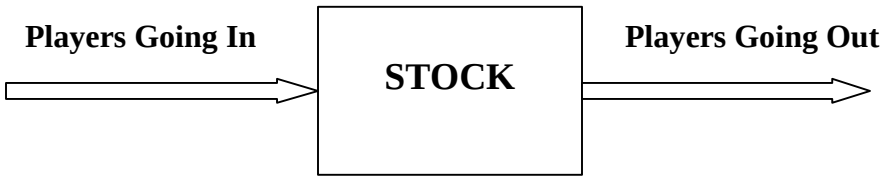
1. Ahead of time, prepare a large blank table and graph on the easel or board.

Round	Players in the Stock	Players Going In	Players Going Out
Start			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			



Note: label the vertical axis with the number of students in the class.

Also, designate a place in the room for the players to stand and be counted – this is called the "stock." Delineate the stock area with rope or masking tape on the floor and create pathways to be used as the "flows" through which players enter and exit the stock, again using rope or tape.



2. Explain to the students that they will be playing a game and keeping track of the number of players in the stock area. As they play, students will take turns entering and leaving the stock through the flow pathways.

3. Announce the rules for the first game. Record these initial values on the first line of the chart.

A. In the stock to start: 0 players
B. Inflow each round: 2 players going In
C. Outflow each round: 1 player going Out

4. Ask two volunteers to walk through the In flow and enter the stock. Ask one of them to exit through the Out flow. Count how many players now remain in the stock – one player. Record that number on the next line in the column for "Players in the Stock" to begin Round 1.

Round	Players in the Stock	Players Going In	Players Going Out
Start	0	2	1
1	1		
2			
3			

5. Choose two new volunteers and play another round. Record 2 Players Going In and 1 Player Going Out.

- ? Count how many players remain in the stock (2) and enter this number to begin Round 2.
- ? Repeat this process, recording the new numbers on the table. Students will soon be able to make predictions as they see patterns emerge.
- ? Guide their predictions with questions.

? **Before playing, what will the values on the table be after the next round?**

? **What would the values be after 15 rounds? 32 rounds?**

The number of players in the stock will continue to increase by one each round. There will be 15 students in the stock in Round 15.

Round	Players in the Stock	Players Going In	Players Going Out
Start	0	2	1
1	1	2	1
2	2	2	1
3	3	2	1
4	4	2	1
5	5	2	1
6	6	2	1
7	7		
8			
9			
10			

6. After playing and recording several rounds, begin drawing the graph. Create a line graph by plotting the data points for the people in the stock and connecting the points.

Point out that the vertical axis is labeled "Players in the Stock". The horizontal axis measures time, counted in rounds played. The graph shows how the stock behaves during the time that the game is played. We call this a *behavior over time graph*.

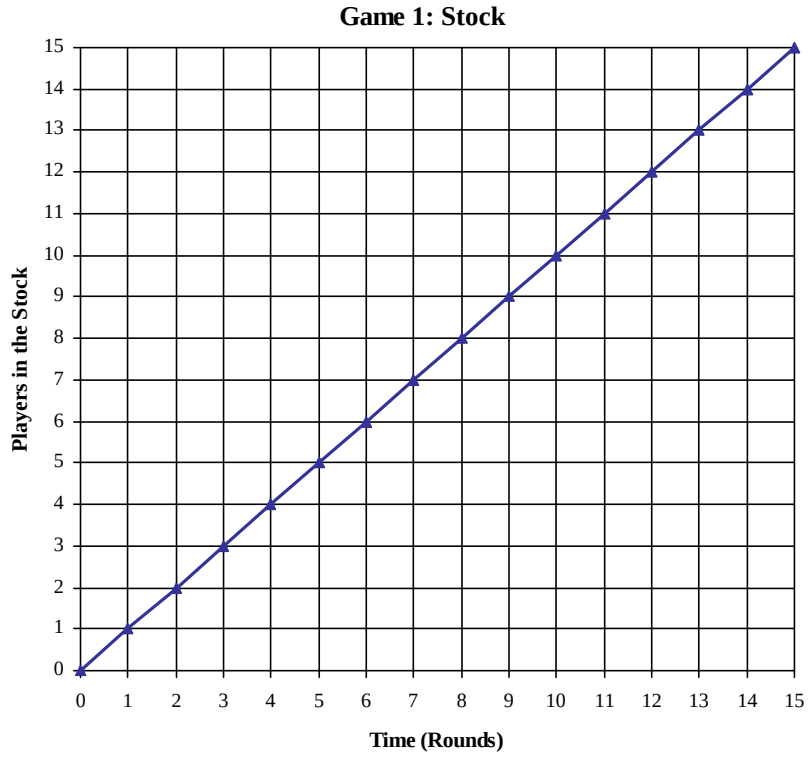
Be sure to differentiate between the students in the designated area each round (the stock) and the players entering and leaving each round (the flows). First plot the stock as shown in the first graph on the next page, then plot the flows. Plotting the flows will produce horizontal lines because the flows are constant, as shown the second graph.

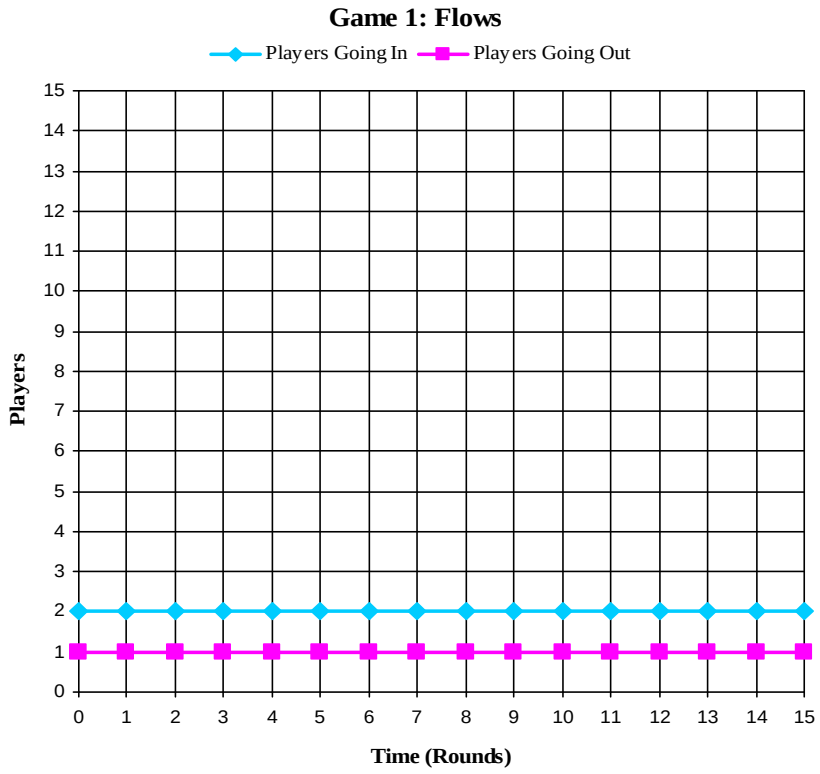
Again, ask students to make predictions about the stock.

? **What will the line look like after the next round? 15 rounds?**

The line will continue with the same diagonal slope.

In the In and Out Game, students experience how a quantity increases or decreases by physically acting it out. Then, they use graphs to consider and communicate their ideas about change over time.


Game 1: Stock
Players in the Stock
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (Rounds)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


Game 1: Flows
Players Going In
Players Going Out
Players
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (Rounds)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

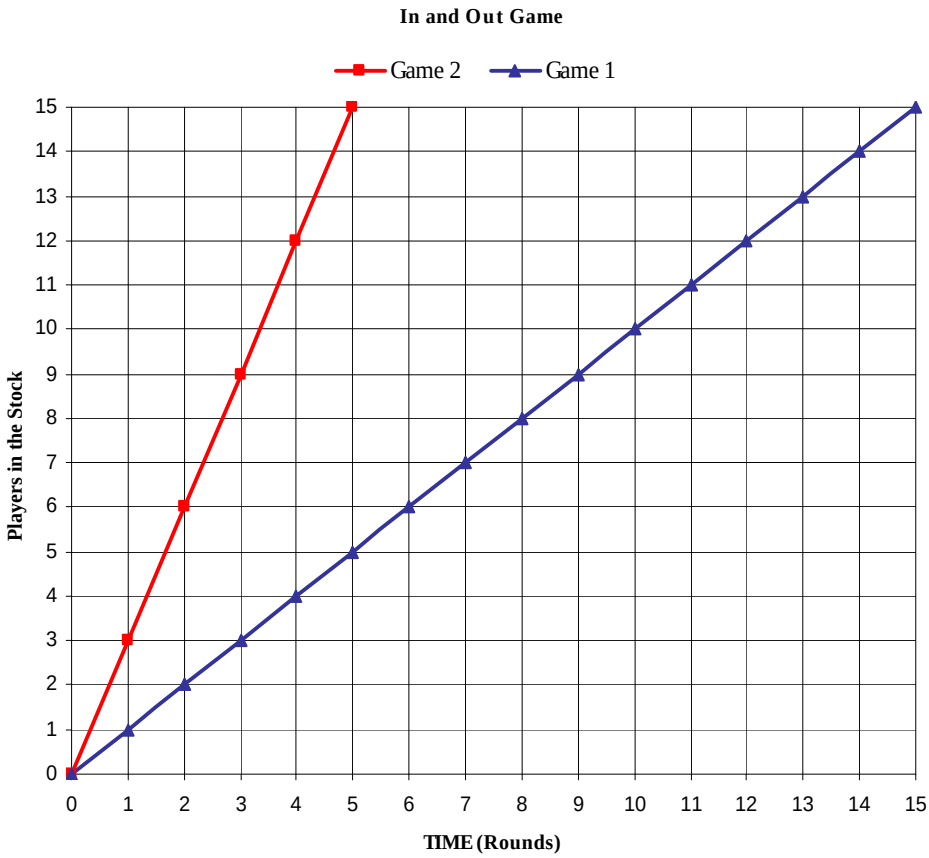
7. Prepare students to play **Game 2**, this time with a different set of rules. There are three rule choices to make for each game:

A. How many players are in the stock to start the game.
B. Inflow: How many go In each round
C. Outflow: How many go Out each round.

Once the rules are established, they cannot be changed until you end the game and begin another. Use the following rules for the Game 2

A. In the stock to start: 0
B. Inflow each turn: 5
C. Outflow each turn: 2

Enter these initial values on a new table and follow the same procedure as the first game. Walk through a few rounds of the game and record the data on a new table. However, graph the stock of Game 2 on the *same* graph as Game 1 in a *different color* so that students can compare the two lines.



Bringing the Lesson Home

After students play the game, be sure to give them enough time to digest what they have learned. This is their opportunity to develop critical thinking skills and apply the lesson more broadly.

Use the graph to focus a discussion on what happened in the game using questions like these.

? **How does the graph show us what happened to the number of players in the stock in Game 1 and Game 2?**

In both games, the number of players in the stock grew over time because more players were going in than going out each round.

? **How are the lines for Game 1 and Game 2 similar?**

Encourage answers such as: Both lines are straight; both show that the stock is increasing at a steady rate; they both start at 0; etc.

? **How are they different?**

While older students can talk in terms of slope, younger students may use words like "steeper" and "flatter" to describe the different rates of change.

? **Which line is steeper? Why?**

The graph for Game 2 is steeper, because more players stayed in the stock each round. The difference between inflow and outflow was greater than in the first game.

Encourage students to deepen their thinking.

? **What makes a stock change?**

Inflows and outflows cause a stock to change – in this case, students going in and out make the number of students in the stock change over time.

? **How can we make the behavior over time graph of the stock steeper?**

Increase the inflow or decrease the outflow so that the stock increases at a faster rate.

? **How would the graph be different if there were some players in the stock at the start of the game?**

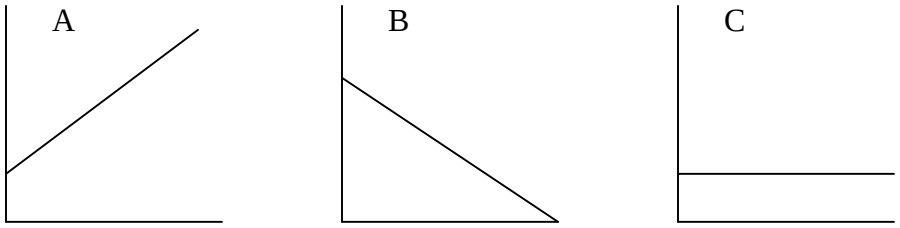
The line would not begin at zero at the beginning of the game. (Graph A)

? **What happens when an outflow is larger than the inflow?**

The stock decreases. The line will go down and might reach zero. (Graph B)

? **What happens when the inflow and outflow are equal, say, 3 In and 3 Out each round?**

The graph of the stock is a horizontal line, because the stock remains constant. (Graph C)



(Alternatively, present students with these three graphs and ask them to define the game rules that produce them.)

? **Ask students if they can think of any experiences in life that resemble the In and Out Game. What makes the stock increase or decrease over time?**

Encourage students to apply the lesson to a range of examples.

- *Money in a bank, piggy bank or pocket over a week or month*
- *Populations of humans and others species over years*
- *Water in a bathtub over minutes, or a pond over a year*
- *Passengers on a train or bus over a day*
- *People in a store, in the school, or in the lunchroom over an hour or day*
- *The weight of their book bags throughout the day*
- *Their hunger, fatigue or happiness over the course of a day or week*

Stocks and Flows

The In and Out Game is a simulation for any stock with flows in and out. Any change over time can be viewed as an accumulation, or stock, that is increased by its inflows and decreased by its outflows.

[1] An expanded version of this game, "The In and Out Game: A Preliminary System Dynamics Modeling Lesson" by Ticotsky, Quaden and Lyneis, 1999, is available from the Creative Learning Exchange at www.clexchange.org. It includes adaptations for primary, upper elementary and middle school students, plus complete instructions to help students build their own system dynamics computer models of the game.

The In and Out Game

This lesson builds on the classroom activities described in ***The Shape of Change,*** *by Rob Quaden, Alan Ticotsky and Debra Lyneis, 2004, The Creative Learning Exchange. You can download the text of the original single lesson or get the graphics and layout in the complete book from the CLE at www.clexchange.org.*

The Shape of Change

In Lesson 1 of the ***Shape of Change***, students played a game to understand how things change over time. Players physically moved into and out of a "stock." They observed how the total number of students in the stock changed as students entered and left, and they used behavior over time graphs to record and interpret the changes. See Pages 7-16 of ***The Shape of Change*** for the complete lesson.

Overview

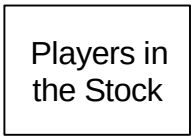
The In and Out Game illustrates two fundamental concepts in a concrete way.

- **Stocks** are accumulations, or quantities that can increase or decrease over time.
- Stocks are controlled by **flows**, which represent the movement into or out of the stocks.

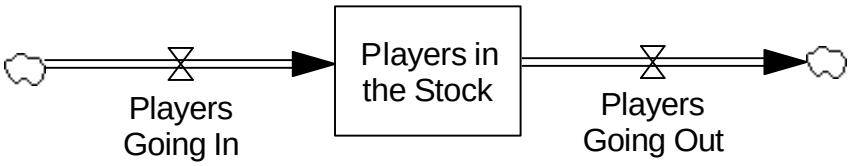
For example, the amount of water in a bathtub can be represented by a stock. Water flowing in through the faucet and water flowing out through the drain can be represented by flows. The amount of water in the bathtub at any point is determined by how much water has flowed in and out over time.

Seeing the structure

1. Introduce the students to the symbols of a stock/flow map. **Stocks** are accumulations and are drawn as rectangles. In the In and Out Game, the number of students who are in the circle at the start of each round is represented by a stock. Have students suggest a name for the stock. The name of a stock should be a noun or noun phrase.



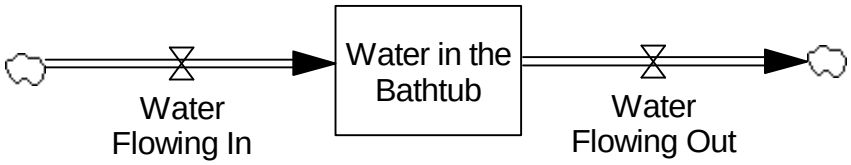
2. A stock can be changed only by a **flow**. Ask students how the stock of "Players in the Stock" changed over time. Students who have played the game will know intuitively that people entering or people leaving caused changes to the stock. These are the flows. (It is sometimes helpful to identify the flows using "–ing" words to denote actions, such as entering, leaving, going in, going out, etc.)



3. In this map, the pipes represent the flows. The valves in the center of each pipe indicate that the flows can be controlled. For example, in the game, the rule for the number of students entering and leaving was changed several times.

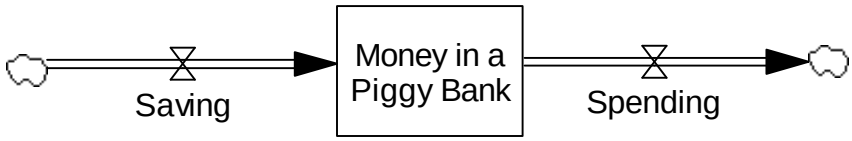
   The **clouds** represent the boundaries of the map: in this game it is not important where the incoming people come from, or where the leaving people go. We are only concerned with the flow of people into and out of the stock.

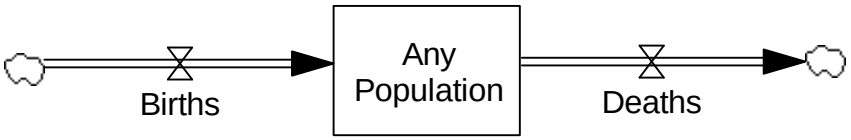
4. Time is implicit in a stock/flow map. The stock accumulates and drains as quantities flow in or out *over time*. In the In and Out Game, players entered and left *each round*. In a bathtub, water flows in or out in gallons of water *per minute*.

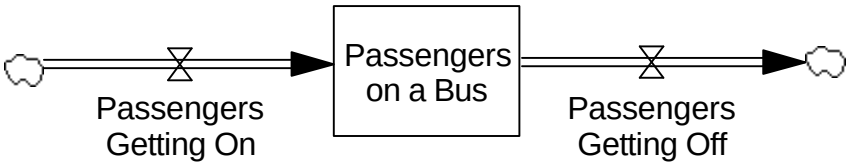


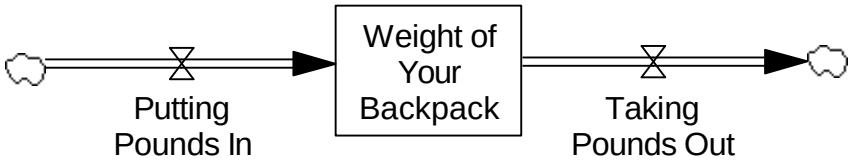
? **Can you think of real life examples of stocks and flows?**

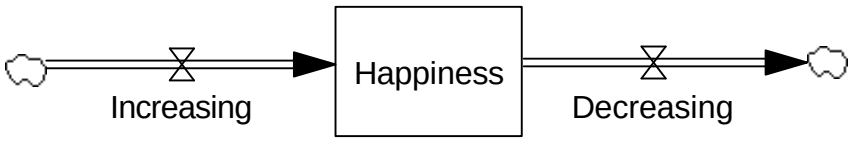
Encourage students to draw their examples in the form of stock/flow maps. Ask the students to sort their maps into categories and explain their reasoning. It is very powerful for students to see that a wide variety of examples can be classified using this generic structure. These are some examples:



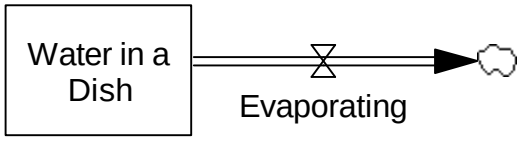


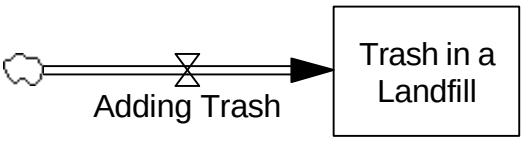






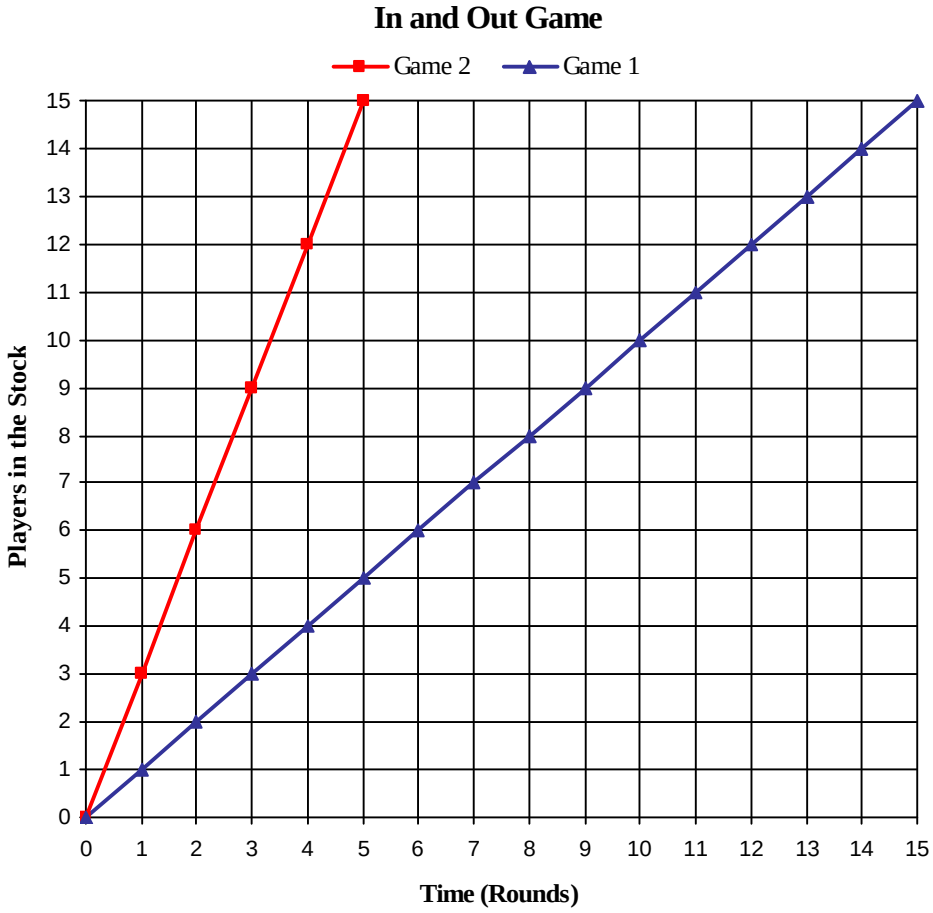
A stock can also have just one flow.





? **Thinking back to the In and Out Game, how could you explain the graphs in terms of stocks and flows?**

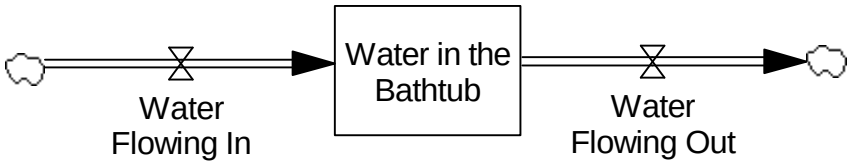
The stocks increased over time because the inflows were greater than the outflows. For example, in Game 1 the inflow was two students entering each round, and the outflow was one student leaving each round, so the stock of students grew by one student each round. In Game 2, with five students entering and only two students leaving, the stock grew even faster each round.



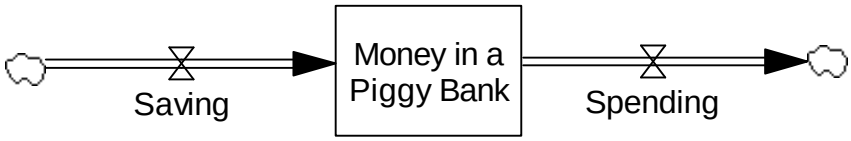
The total number of players in the stock depended on how many students flowed in and out each round.

? **Take another look at your examples of stocks and flows. How can a stock change?**

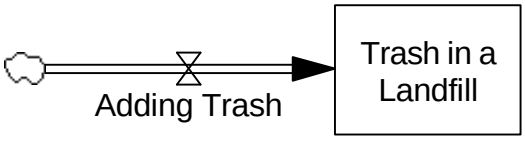
- *If you have a bathtub, you can change the level of water in it by pouring water in through the faucet or letting water out through the drain. Although you can alter the rates of flow by adjusting the faucet or slowing the drain, the flows in and out are the only ways to change the water level in the tub.*



- *If you have money in a piggy bank, you can accumulate more money if you save more and/or spend less. Any amount of money you deposit will increase the balance, but larger deposits will cause it to grow more quickly and smaller deposits will cause it to grow more slowly. The same thing works for withdrawals. Any withdrawal will drain the balance, but bigger expenditures will drain it more quickly. To build a bigger nest egg, you need to increase the inflow or decrease the outflow of money, or both.*



- *If you have a landfill where trash is buried, the landfill will continue to fill up because there are no outflows. You can slow the rate of filling by encouraging recycling, but trash will still pile up. You cannot decrease the stock of trash without adding an outflow: digging trash up hauling it somewhere else—where the same problem will arise again.*



- *Tell the story of other examples to see how stocks and flows can help you think about change in the real world. Stocks can be changed **only** by their flows.*