

Paper Clip Factory Analogy: a simple model, a simple system

Purpose

- To provide students with an opportunity to explore the essential components of a simple system or model by using a simulation activity in which students enact the parts of a paper clip manufacturing business.
- In order to develop an understanding of the components of a system that represents a simple model, students will be provided with the opportunity to collect and analyze data produced during the simulation as well as the chance to translate the data into a generalized 1-box model that can be manipulated to produce varying outcomes.

Overview

Students will work in small groups that represent the components of a simple paper clip manufacturing business including the factory, store, and customers. Through a simulation activity in which students act out the paper clip manufacturing system, students will take part in one part of a simple system. As a result of the simulation, students will identify and analyze the basic parts of a simple system or model including inputs, outputs, and stocks.

Essential Question

How does the paper clip factory simulation represent a simple system or model?

Student Outcomes

- Students will simulate a basic system that represents a simple model of a paper clip manufacturing business
- Students will collect data and record values in data table and/or graph during the simulation
- Students will analyze final data collection and describe patterns of the inputs and outputs of the paper clip factory system using qualitative descriptions and mathematical equations
- Students will explore the paper clip analogy and compare to the schematic diagram of a 1-box model labeled with key terms (i.e., input, output, pool) in order to learn these modeling terms
- Students will manipulate the variables of the model in order to obtain an expected outcome and analyze the strategy used for obtaining the particular outcome
- Students will write a response to the essential question: how does the paper clip factory simulation represent a simple system or model?

Science Concepts

- Modeling
- Components of a system
- The manipulation of models to alter outcomes

Time

60-90 minutes

Level

Middle or high school

Materials and Tools

- 5-10 boxes of paper clips
- data sheets photocopied (paper copy & overhead) ---(Appendix B)

GLOBE Carbon Cycle

- overhead projector & wet erase pens
- markers for white board
- bell or whistle
- facilitator (1), factory worker(5-9), store worker(3-4), and customer(5-9) roles written out on index cards ---(Appendix A)
 - # of factory workers and customers should be equal (at least at the start)
 - photocopy enough descriptions so that every student has a copy
- open and closed sign for store ---(Appendix C)
- copies of final assessment ---(Appendix D)

Preparation

Gather all materials. Write essential question somewhere visible in the classroom. Sketch a graph on the white board to be used to record # clips in the store at the end of each day. The x-axis should be labeled “days” (1-10) and the y-axis should be labeled “# of paper clips in store at the end of the day”.

Pre-requisites

This is an introductory modeling activity. It is meant to prepare students for the use of computer models associated with the GLOBE Carbon Cycle curriculum. Some background in data recording on charts and graphing skills would be helpful.

Background

Scientists use models in many fields of study. Models can be simple or very complex. In general, the purpose of models is to help improve the scientists’ understanding of a system and the associated components of that system or multiple systems. In addition, scientists can use models in order to understand the interactions of the numerous components of a system and to consider theoretical outcomes of particular real-world scenarios.

The basic part of any system includes stocks and flows. Stocks, also known as pools, are places where an entity is stored. Flows or fluxes describe the process or movement of that entity from one stock to another. For example, in the global carbon cycle the plant pool/stock stores carbon in the form of glucose and other organic molecules within the plant. The flow or flux into this plant pool is a result of photosynthesis, which removes carbon dioxide from the atmosphere pool or stock. The carbon flow or flux out of this plant pool is due to the plant respiration process that releases carbon dioxide back into the atmosphere pool. If the inflow (photosynthesis) and outflow (respiration) are equal the plant pool is said to be in a state of dynamic equilibrium. During equilibrium material is still passing in and out of the stock, however the overall amount in the stock is not changing over time. Equilibrium, also known as steady state, is an important system concept. While in this example we have described the carbon cycle in two pools the complete carbon cycle includes several more pools and fluxes.

What To Do and How To Do It

Engage

- Read aloud the following passage to set the stage for the simulation activity.
- “You are the proud citizens of a small town whose stability & happiness is result of the booming paper clip factory in the center of town. It is your job to study this booming business and to model its activity for 10 days. Some of you will be *factory-workers*. At the sound of the bell every morning each *factory-worker* will have produced 2 paper clips. Paper clips are transported by *factory-workers* to the paper clip store. Some of you will be *store-workers* and you will carefully count the number of clips available before you open the store to the public each day. Some of you will be eager *customers*. Current demand for paper clips is 1 paper clip per

customer per day. All additional paper clips not sold by the end of the day remain in the store and are recounted by *store-workers* at the end of the day.” (5 minutes)

Explore

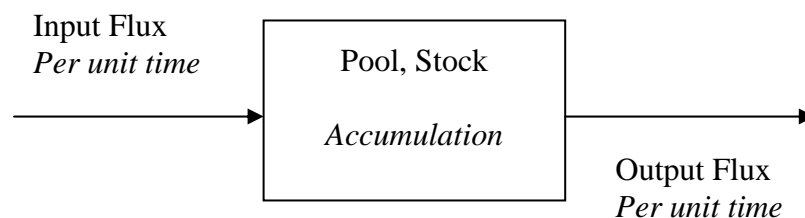
- Divide students into 3 groups: *factory-workers* (*input flow*), *store-workers* (*stock*), *customers* (*output flow*) using the prepared index cards that indicate students’ role and the associated rules (see *Appendix A*).
 - i. Make the *factory* and *customer* groups equal to each other.
- Explain the following directions, making each person’s responsibility very clear. Display on an overhead of the data table (*Appendix B*) in order to make your directions clear. Tell students they will begin the activity only when everyone understands their roles and when the *facilitator* rings the bell to indicate the store is ready to receive the first factory delivery.
 - Give each student in the factory a handful of or box of paper clips (at least 20 per student). Instruct them that each of them will give 2 clips at a time to the store group at the chime of the bell or whistle each day of the simulation. (The *facilitator*, likely the classroom teacher, will be responsible for the bell.)
 - Tell students that after all *factory-workers* supply the store with their clips, *store-workers* count # of clips produced per worker, # of workers, and total clips produced. One *store-worker* announces this to the public and records this on the class data table displayed on the board (*Appendix B*). (Note: On the first day the number of clips available will equal the factory delivery of clips because the store was sold-out of paper clips the previous day.)
 - Make sure students understand the data that is being entered in the class table/chart and can see and hear class results.
 - It may be helpful to encourage each student to write down the results while the *store-worker* records them on the overhead.
 - It also may be helpful to graph the results of the simulation.
 - Once announcements are completed and data is recorded, *store-workers* open the store by displaying the open sign (*Appendix C*).
 - Tell students that once the store is open then the members of the *customer* group each take 1 paper clip from the store group in order to “purchase” the clips. After *customers* are finished “purchasing” clips *store-workers* again count, record, and announce # of clips purchased per customer, # of customers, total # clips purchased, total # clips sold to date, and # clips remaining in the store or the inventory stock. The table/chart can be filled in on the overhead displayed on the board and by each student or group.
 - Ask all students to read their index cards quietly to themselves in order to review these directions and to speak briefly with their group in order to clarify questions. Give students a minute to ask you any remaining clarifying questions.
 - Remind students that each of them has a role and for us to understand the efficiency and working of the factory system we need to work with intention and as a team. Start the simulation with the bell which signifies the end of the first morning and that the store is ready to receive the factory’s delivery. Give all groups time to complete their roles before you ring the bell again.
 - Continue in this pattern until you have completed the cycle 5 times (5 “days” worth of data). (20 minutes)

Explain

- Gather all students’ attention and facilitate a discussion that helps students to begin to interpret the initial data set when the simulation is partially completed. Suggested questions include:
 - Based on the data chart and/or graph...
 1. After 5 days of factory work what do you notice about your number of paper clips available in the store (ie, inventory stock) at the end of each day? 2. Do

you see any patterns in your data? 3. How many clips were produced per day? Did this change? Why? 4. How many clips were purchased per day? Remain the same? Why?

- This accumulation of paper clips is why the town is flourishing. It also describes an aspect of any simple model. Remember we used this simulation as an analogy for simple scientific models that can be used to understand dynamics of a system. What we just did in the paper clip activity was an example of a 1-box model.
- Draw the model on the board in standard box and arrow format. Label the pool and fluxes. Elicit students' responses in order to include the input and output values in the schematic. Discuss the interchangeable terminology used in models. (10 minutes)
 - i. *Box, pool, reservoir, stock*
 - ii. *Arrow, flow, flux, transfer* (applies to both inputs and outputs)



Elaborate/Investigate

- Direct students back to their groups. Complete the simulation.
- Before the store rings the bell, change the input number of clips (ie, factory production) or the output number of clips (ie, customer purchases) to manipulate the system and to show change in the model. For instance, change the number of clips each *factory-worker* (*input flux*) produces to 3 clips and observe the simulation for 3 more days. Again change one of the fluxes for the final 2 days of the simulation. Or make clip production and purchase equal, to demonstrate the concept of equilibrium.
- Ask students to consider the following questions in their science journal: 1. How did the paper clip model change on day 6? 2. How did the paper clip model change on day 9? 3. How do you think your change affected the final clip count at the end of the 10 days? 4. Do you think there are more or less paper clips in the store than if you had continued the same pattern as in the first 5 days? (20 minutes)

Evaluate/Wrap-Up

- Bring the whole class together and discuss their journaling. Discuss math in models and explain that math can be simple. Their homework will challenge them to consider the mathematical equations that describe the model. Also remind students that models don't have to be complicated to be useful.
- Explain expectations for follow-up assessment. This assessment can be used as homework or the following class period. (5 minutes)

Assessment

- See handout, *Appendix D* --- This follow-up assessment can be used as homework or as another class activity.
 - Students should label a 1-box model diagram based on the variables used in the **Paper Clip Factory** exercise
 - Using the diagram and data table/chart from the **Paper Clip Factory** exercise have students describe the process using mathematical equations.

- ii. How would you calculate Total Number of Clips Produced Per Day? [(# clips produced per worker) x (# factory workers this day) = clips produced/this day]
- iii. Inventory stock: paperclips remaining at the end of the day? [(total # of clips produced this day) – (total # of clips purchased this day) + (inventory from previous day) = Inventory Stock]
- iv. Paperclips sold to date? [(total # of clips purchased this day) + (total clips sold to date from the previous day)] = total paperclips sold to date
 1. CHECK: Does this match the number that students in the Store group counted? For which day? Why?

- Challenge students to determine a way to maintain the stock of paper clips at 25 per day by the end of the day.
- In-class: Discussion and sharing of schematics and strategies.
 - Have students work in small, collaborative groups and then have students share their labeled diagrams, math, and thinking.

Extensions

- Make up a new scenario in which you change only one variable and discuss how it affects the outcome of the model. (e.g., Consider and explain how your results might look if you changed the number of paper clips produced at the factory or bought by the customer?)
- Use the Paperclip Factory computer model in the free iSee Player to show students how useful computer models are in helping to process information and to prepare them for later modeling activities.
- Students can brainstorm examples of other 1-box models, they should bring their top ideas to class the following day. This activity will show that students really understand the concept of 1-box models. You may challenge students to expand their 1-box models into several boxes, describe the math behind their models, or build their models in STELLA (if your school has selected to purchase the software).

Adaptations

- Upper elementary school students (5th and 6th grades) can conduct this activity if it is adjusted to their abilities. One 5th grade class had the students working at the factory actually creating the paper clips out of previously unbent paper clips in order to make the lesson more active.
- The customer group has the most lag time during this activity. We suggest giving them an extra challenge, such as a word search that relates to the activity and/or the carbon cycle, in order to help maintain their focus.
- During the data analysis and interpretation work some students will be ready to translate the input and output fluxes into mathematical sentences while others will benefit from simply drawing a schematic diagram showing the paper clip business model components.

APPENDIX A

ROLE: FACILITATOR

- You keep track of the day and time. You ring the bell at the beginning of each morning and announce which day it is. Only ring the bell when the store-workers indicate that they are ready to receive delivery of paper clips from the factory.

ROLE: PAPER CLIP FACTORY-WORKER

- You work at the well-known paper clip factory and produce 2 clips per day.
- At the sound of the bell each morning you deliver your 2 clips (no more or no less unless told otherwise) to the paper clip store.
- Following this delivery you return to the factory.
- Record the factory production as announced by the store-worker on your datasheet.
- As you are part of a team you work with intention, focus, and quietly in order to be able to hear important announcements coming from the paper clip store.

ROLE: PAPER CLIP STORE-WORKER

- You work at the well-known paper clip store.
- At the sound of the bell each morning you collect all clips from the factory-workers and count the total number of clips produced that day (also count # clips produced by each worker and # of workers). You announce the data to the public each day and record the number on the class chart.
 - We suggest dividing up these responsibilities among your store members. One individual can be responsible for the opening and closing the store by displaying the sign; one person can be responsible for counting the clips and announcing the amount to the public; one can record the data on the class chart, and one or several people are in charge of dealing with customers.
- After you have announced the number of paper clips produced that day you may open your store by displaying the *open* sign.
- When you are open for business you only sell 1 clip per consumer per day (do this by handing one clip to each consumer).
- In order to keep careful track of the clips you also count the clips at the end of the day after all purchases are completed (also count customer purchases). You again announce the numbers to the public and record the numbers on your datasheet. Then you close the store by displaying the *closed* sign.
- As you are part of a team you work with intention, focus, and speak clearly when making important announcements to the public.

ROLE: PAPER CLIP CUSTOMER

- You are a proud daily customer of paper clips, which are used throughout town.
- Before the store opens you will record the number of paper clips produced and available at the store on your data chart.
- When the store displays its open sign you may purchase 1 clip per day (no more or no less unless told otherwise).
- Each day the store is open you must purchase a clip.
- Once the store-workers announce the number of purchases and paper clips remaining in the store at the end of the day, you record these values on your data chart.
- As you are part of a team you work with intention, focus, and quietly in order to be able to hear important announcements coming from the paper clip store.

APPENDIX B

Paper Clip Factory Data Table

Time	Factory Production			Customer Purchases			Store	
Day	# of paper clips produced per worker	# of workers this day	Total # paper clips produced this day	# of paper clips purchased per customer	# of customers this day	Total paper clips purchased this day	Total # paper clips sold to date	Inventory stock: paper clips remaining this day
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

OPEN

STORE

STORE

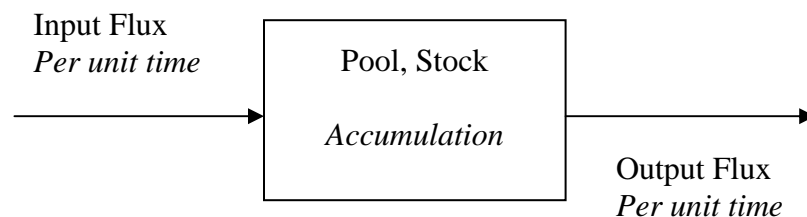
CLOSED

APPENDIX D

1. Draw a 1-box model in standard box and arrow format (see below) illustrating the factory system you just simulated for a set of particular days. Label the stocks and flows with the factory terms such as Store, Clips Produced, and so on. * Also indicate which days of the simulation you are modeling.

2. Above your diagram indicate which days of the simulation you are modeling. Now include the input and output values during that simulation by writing a simple equation that explains each. For example, how do you calculate Total Number of Clips Produced Per Day (Input Flux)?

$$[(\# \text{ clips}) \times (\# \text{ factory workers}) = \text{clips produced/day}]$$



3. Answer the following essential question in a few sentences: How does the paper clip factory simulation represent a simple system or model?

CHALLENGE

4. Determine a way to maintain the stock of paper clips at 25 per day by the end of the day over several days. Feel free to use the backside of your data sheet to check your strategy. Be able to explain your strategy to the class. Draw another diagram to help you illustrate your new strategy and model.