Lesson 3:
Marginal Analysis: How Clean Is Clean Enough?

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Standards and Benchmarks (see page 3.12)

Lesson Description

In this lesson, students participate in a short carpet-cleaning demonstration to illustrate that the marginal cost of cleaning something increases as more and more is cleaned. After thinking about the damage associated with pollution, students then decide what factors determine how clean the environment should be.

Grade Level

High School

Concepts

Marginal cost

Pollution

Objectives

Students will be able to

- describe why the marginal cost of cleaning up pollution (or preventing pollution) increases as more pollution is cleaned up (prevented), and
- decide how much should be cleaned up based on characteristics of the pollution and the costs of cleaning up the pollution.

Compelling Question

Should businesses be required to not pollute at all when they produce their products?

Time Required

45 minutes

Materials

- PowerPoint Slides 3.1-3.6
- Handout 3-1, one copy for each student (optional)
- Handout 3-2, one copy for each student
- Two small carpet samples (about 2' x 2' each)
- Six 4-oz cups with lids, each filled with debris (see Preparation section)
- Paper towels
- Dry black or navy beans
- Small bits of paper (such as from a hole punch)
- Glitter

Preparation

- Before the start of class, set out the two small carpet samples and six small cups of debris as described below. Place the rugs so that students see them as they enter the classroom.
- Divide the six cups into two sets of three. Each set of three cups should be filled with the following: 1) a paper towel balled up as trash; 2) dry black or navy beans; and 3) small bits of paper with a bit of glitter mixed in. (NOTE: While the ingredients are initially distributed as described above, it is not required that the ingredients stay in separate cups. The ingredients will get mixed together during the activity, but each cup should be filled to the top and sealed with a lid. This makes it easier if the simulation is being done for multiple classes.)

Introduction

Economics teaches that decisions are made by comparing the marginal benefits to the marginal costs of an action. This also applies to the environment. While a pristine environment has some benefits, the marginal cost of keeping an environment that clean tends to be very high. In general, the cleaner the environment, the higher the marginal cost of cleaning the environment. Although, the marginal benefit of going from a clean environment to one that is pristine is not very high. So if we compare marginal costs to marginal benefits, the best decision usually isn't to have a pristine environment. Conversely, if there is a highly polluted environment, the marginal benefit of some clean up is high, while the marginal cost of cleaning up the worst of the pollution is low. This implies that no pollution control at all is not the best decision for society, either. As with most decisions, the best level of pollution lies between the two extremes.

Procedure

1. Display Slide 3.2. Ask how many students agree with statement #1 and how many agree with statement #2. Invite a few students to explain their answers. (*Answers will vary.*)

2. Tell the students you will conduct a classroom experiment involving cleaning up pollution in the environment. Ask for four student volunteers and group them into two teams of two students. Have the two teams come to the front of the class and stand in front of the two carpets. Explain the following:

    - The rugs each represent waste materials that flow into a lake. Explain that a factory emits this pollution, a substance that harms the environment, into the lakes when producing its product. Take out the cups of debris. Dump three cups (one of each type of debris) onto each of the two carpets. Spread the debris around the carpet.
    - Tell the two teams they are to clean the dirty rugs (pollution) before the pollution flows into nearby lakes. Explain that they will have three rounds to clean the carpets. For each round, their goal will be to pick up the trash and deposit it into one of the cups as fast as possible. A round will conclude when each team has filled and put the lid on one of their cups. The team who fills a cup the fastest will win the round. To make the experiment work, tell the students they cannot simply pick up the rug and pour the trash into the cup. Also, they cannot use pieces of trash to sweep away, collect, or pick up other pieces of trash. They are to use only their hands to pick up the trash.
    - Appoint a student with a watch that shows seconds or a cell phone with a stopwatch feature as timekeeper. Tell him or her to time each round carefully from when you say start until one of the teams fills a cup. Have the rest of the class sit or stand so they can observe the cleanup.

3. Tell the students to get ready to begin the first round. Remind the two teams that they are in a race and that the first team who fills a cup with debris and covers it with the lid wins the round. The round is over when both teams have completed the task. When the students are ready, begin the round. (NOTE: This round is won quickly by putting a paper towel back into the first cup and sealing the lid.) When the round is finished, ask the timekeeper for the winning time and record it on the board.

4. Repeat the race for two more rounds, reminding the timekeeper to keep careful time. End each round when both teams have each filled and put the lid on a cup. Be sure to record the winning times on the board. For the last cup, you can call time when the cup looks full, even if a bit of glitter remains on the carpet. (NOTE: The second round will go slower than the first because it will take the two teams more time to fill a second cup. The cup will be filled primarily with the beans and some paper bits. The third round will take the longest because the remaining paper bits take a while to pick up.)

5. After the third round, ask the students if the rug is perfectly clean. (*Eagle-eyed students will note the presence of some glitter in the carpet.*) Ask the students how long it would take to clean the final bits of glitter. (*A long time*) Point out that to clean the waste to keep the nearby lake in its original pristine state is very costly in terms of time and effort. Thank the student volunteers for participating and have them sit in their usual places.

6. Project Slide 3.3 or draw the following table on the board and fill in the three winning times (one for each round). The italicized numbers in columns 3 and 4 should be from your time-keeper—the following are examples:

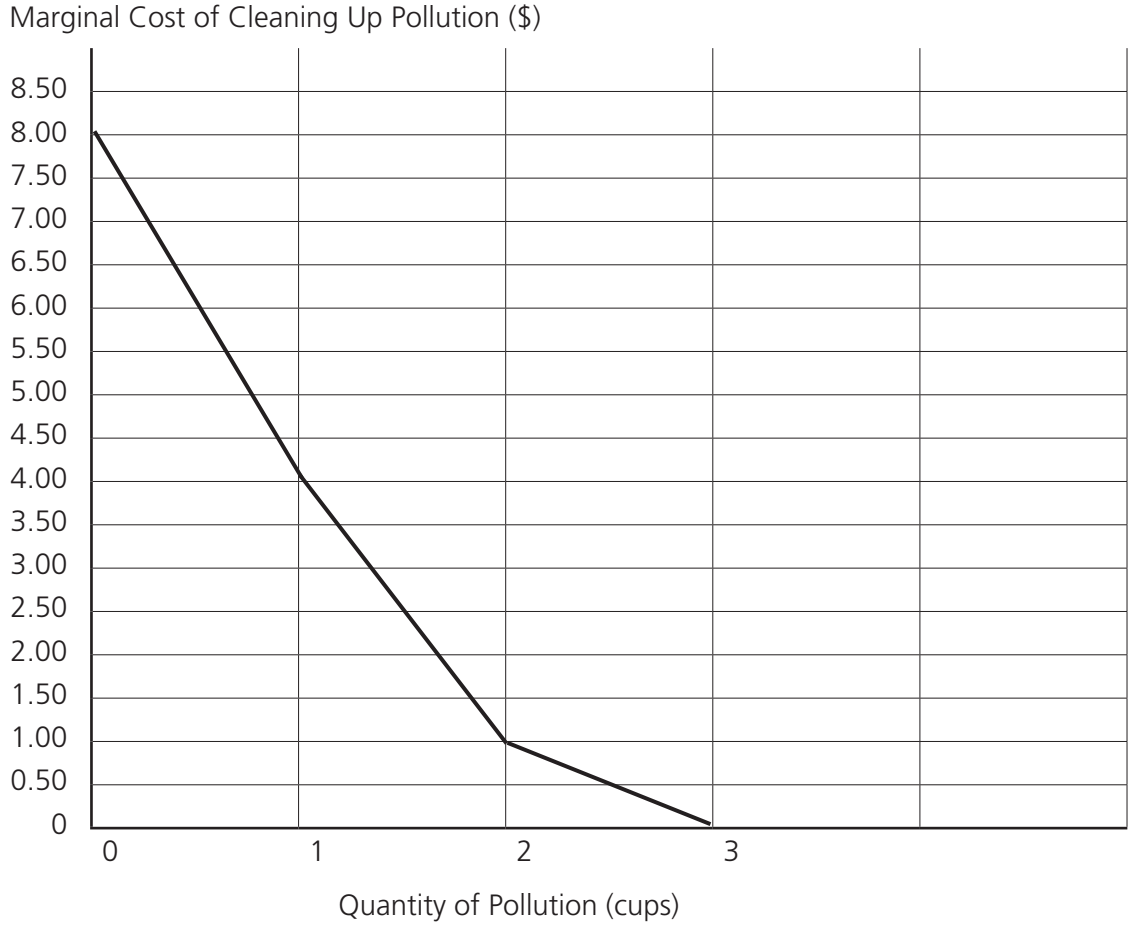
Pollution cleaned (debris in cups)	Pollution in environment (debris from cups)	Time in seconds	Marginal cost ($360 per hour per person = $0.20 per second for both)
0	3	*0*	$0
1	2	*5*	*$1*
2	1	*20*	*$4*
3	0	*40*	*$8*

7. Explain that the table shows the pollution cleaned (debris in cups), the pollution left to flow into the lake (left on the rug), the time it took to clean up the debris, and the marginal cost of the cleanup for each cup. Tell the students that marginal in economics means additional, so the marginal cost is how much it costs to clean up an additional cup of pollution.

8. Explain that the cost is calculated at $360 per hour for each worker. This means that it is $720 per hour for the two workers on a team. This is equivalent to $12 a minute, or $0.20 a second for both workers. Explain that while this is a high estimate for their labor, cleaning up pollution requires labor, materials, and machine rental, so this cost includes the cost of all these items needed for pollution control. Discuss the following:
   - What happens to the marginal cost of cleanup as more pollution is cleaned up? (*The marginal cost increases.*)
   - Why does the marginal cost increase? (*The first cup of pollution was easy to clean, but more time was needed to clean up the tinier pieces of debris.*)
   - How long would it take to remove every small piece of remaining glitter? (*Accept any answer above the last cup's time, but it might take around 2 minutes.*) Note to the students that the marginal cost of the last small bit would be very high.

9. Optional graphing activity: Distribute a copy of *Handout 3-1: Graphing the Costs of Cleaning Up Pollution* to each student. Have the students graph the quantity of pollution and the marginal cost of cleaning up pollution. An example is graphed below and on Slide 3.4. Ask

the students why the line rises toward the left axis as less pollution is left in the environment. (*The marginal cost of cleaning up increases as more pollution is cleaned up.*)



10. Tell the students to try to imagine the decisionmaking process of a business that pollutes. Discuss the following:
    - How much pollution would a business clean up if they were not required to do so? (*The students should answer none, although some may suggest that a business might clean up some pollution as a matter of goodwill toward the community.*)
    - Why would businesses hesitate to clean up all of the pollution? (*The marginal cost of cleaning every last bit of pollution is extremely high.*)
    - Why are businesses willing to pay to be able to pollute? (*They save the cost of having to clean up the pollution.*)

11. Explain to the students that economists define the **demand** for something as the quantity of a good or service that buyers are willing and able to buy at all possible prices during a certain

time period. Typically, at higher prices people are willing and able to buy smaller quantities, and at lower prices they are willing and able to by larger quantities.

12. Tell the students they are now going to use the data from the rug-cleaning example to determine the demand for pollution by the business. Remind the students that a business will clean up pollution if it is cheaper to clean it up than emit the pollution into the environment. Draw two columns on the board. Label the first column "Price" and the second column "Quantity of Pollution Demanded." Discuss the following:

    - If the price the business must pay to leave pollution on the rug is $8 (or use the highest cost in your simulation), how many cups would the business decide to clean up? (*It would clean up all three cups because the cost of cleaning up is equal to or less than $8—$1 for the first cup, $4 for the second cup, and $8 for the third cup in this example.*) How many units of pollution would the business emit or leave on the rug? (*It would leave 0 cups.*) Write $8 under Price and 0 cups under Quantity of Pollution Demanded.
    - If the price the business must pay to leave pollution on the rug is $4 (or use the second highest cost in your simulation), how many cups would the business decide to clean up? (*It would clean up two cups—$1 for the first cup and $4 for the second cup in this example.*) How many units of pollution would the business emit? (*It would emit one unit or cup; since the cost to clean up a third cup is $8, the business would pay $4 to leave the remaining pollution on the rug.*) Write $4 under Price and 1 cup under Quantity of Pollution Demanded.
    - If the price the business must pay to leave pollution on the rug is $1 (or use the lowest cost in your simulation), how many cups would the business decide to clean up? (*It would clean up one cup—$1 for the first cup in this example.*) How many units of pollution would the business emit? (*It would emit two units; since the costs to clean up the second and third cups are $4 and $8, respectively, the business would leave these units on the rug.*) Write $1 under Price and 2 cups under Quantity of Pollution Demanded.
    - If the price the business must pay to leave pollution on the rug is $0 or free, how many cups would the business decide to clean up? (*It would clean up 0 cups.*) How many units of pollution would the business emit? (*It would emit three units; since the costs to clean up the first, second, and third cups are $1, $4, and $8, respectively, the business would leave these units on the rug.*) Write $0 under price and 3 cups under Quantity of Pollution Demanded. The demand should look like the following:

Price	Quantity of Pollution Demanded
$8	0 cups
$4	1 cup
$1	2 cups
$0	3 cups

- Does the demand for pollution "look like" a typical demand curve where the price and quantity demanded move in opposite directions? (*Yes, it is downward sloping.*)
- Have the students compare the demand for pollution to the table. Are there similarities? (*Yes, students should note that the marginal cost column and quantity of pollution column are the same.*)

13. Tell the students that because businesses compare the price of polluting to the marginal cost of cleaning up pollution, the marginal cost of pollution is essentially the demand curve for pollution. If the marginal cost of cleaning up a unit of pollution is less than or equal to the price a business pays to be able to pollute, the business will clean up that unit. If the marginal cost of cleaning up a unit of pollution is more than the price a business pays to be able to pollute, the business will not clean up that unit. Tell the students the main takeaway from this activity is that the demand for pollution is based on the marginal cost of cleaning up pollution. If the marginal cost of cleaning up pollution increases (maybe because the firm is expanding its production), then the demand for pollution increases. If the marginal cost of cleaning up decreases (maybe because of better pollution control technology), then the demand for pollution decreases.

14. Explain that pollution causes damage to the environment. Ask the students to speculate what happens to the marginal—or additional—damage caused by another unit of pollution as more pollution is put into the environment. (*The students will guess, hopefully, that the marginal damage increases.*) Discuss the following:
    - What is the "best" amount of pollution for society? (*Answers will vary. Some students may say none and others may say some should be allowed.*)
    - Why, based on the demonstration, is "perfectly clean" probably not the best option? (*Students may note the high costs for the business to clean up the pollution.*)
    - Why is letting businesses pollute all they would like not the best option? (*Students may note that the damage caused by pollution is extremely high.*)
    - What is the "best" amount of pollution for society? (*Answers will vary but may be somewhere between perfectly clean and very dirty.*)

15. Conclude the conversation by asking the students to speculate about whether the best amount of pollution to clean up is relatively high or relatively low, based on the characteristics/pollutant you will name (see below and on the slides). Display Slides 3.5 and 3.6, which list the following different scenarios:
    - Polonium-210 (http://www.medicalnewstoday.com/articles/58088.php): Toxicologists estimate that 1 gram of polonium-210 would be enough to kill 50 million people, in addition to another 50 million people who would become ill. (*More clean; high damage to the environment*)

- Household dust in a typical household (*Less clean; low damage to the environment*)
- Household dust in a household with a highly asthmatic child (*More clean; high damage to the environment*)
- Paper airplanes in a classroom (*More clean; low cost to clean up*)
- Glitter on a carpet in a classroom (*Less clean; high cost to clean up*)

16. Display Slide 3.2 again and ask how many agree with statement #1 and statement #2. Probably more students will agree with statement #2 than before. Emphasize that the point of the activity is to compare the marginal benefits to the marginal costs of cleaning up (preventing) environmental pollution when deciding how much pollution should be allowed. The point is not that a clean environment is undesirable, but that trade-offs must be made when trying to decide how clean the environment should be.

Closure

17. Conclude the lesson by asking students what, according to economic thinking, determines how clean the environment should be. (*The exact amount depends on the cost of cleaning up versus the cost of the damage caused by the pollution. The environment will be somewhere between perfectly clean and totally dirty.*)

Assessment

18. Distribute a copy of *Handout 3-2: Assessment* to each student. Allow time for the students to work and then review the answers as follows:

Multiple Choice

1. The environment should be cleaned up more if the cost of cleaning is relatively _____ and the damage caused by the pollutant is relatively _____.
   a. high; high
   b. high; low
   c. *low; high*
   d. low; low

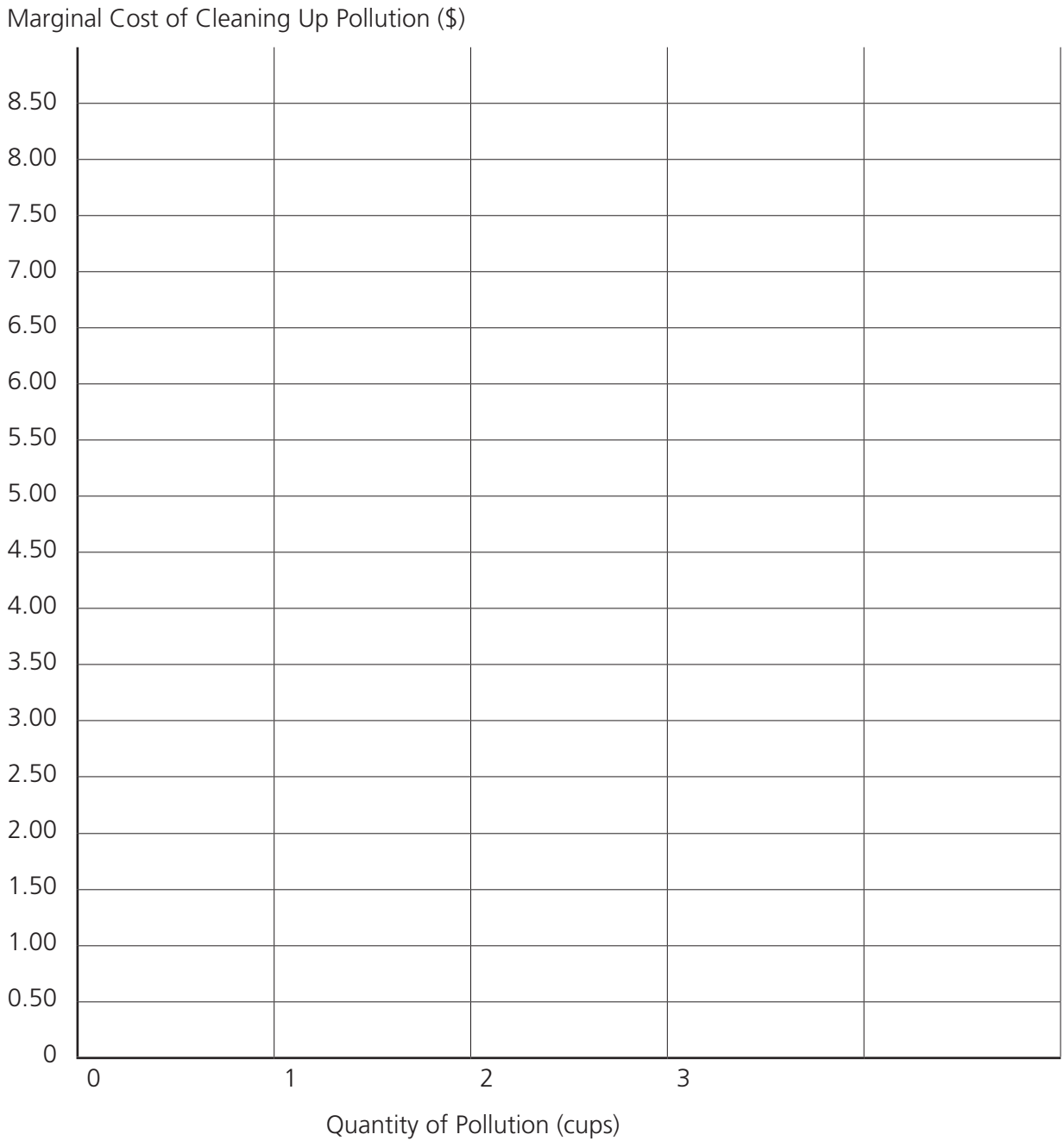
2. A business is trying to clean up a spill of 500 gallons of toxic chemicals that went into a nearby lake. The business has spent $5 million dollars and has managed to clean up 250 gallons. To finish cleaning the lake, a reasonable estimate (based on the simulation in class) would be an additional payment of
   a. $0 to $2 million dollars.
   b. $2 to $4 million dollars.
   c. exactly $5 million dollars.
   d. *over $5 million dollars.*

Short Answer

3. Argue why allowing some quantities of most pollutants into the environment is a reasonable economic policy.

   Most pollutants can be absorbed by the environment in small quantities with little effect on the environment. Because the damage caused is so small, spending a lot of money to keep the environment completely free of the pollutant would be inefficient in that the marginal cost of the damage is less than the marginal cost of cleaning up the pollution.

Handout 3-1: Graphing the Costs of Cleaning Up Pollution



Handout 3-2: Assessment

Multiple Choice

Select the best answer for each of the following questions.

1. The environment should be cleaned up more if the cost of cleaning is relatively _____ and the damage caused by the pollutant is relatively _____.
   a. high; high
   b. high; low
   c. low; high
   d. low; low

2. A business is trying to clean up a spill of 500 gallons of toxic chemicals that went into a nearby lake. The business has spent $5 million dollars and has managed to clean up 250 gallons. To finish cleaning the lake, a reasonable estimate (based on the simulation in class) would be an additional payment of
   a. $0 to $2 million dollars.
   b. $2 to $4 million dollars.
   c. exactly $5 million dollars.
   d. over $5 million dollars.

Short Answer

Write a response to the prompt below using complete sentences and correct grammar and punctuation.

3. Argue why allowing some quantities of most pollutants into the environment is a reasonable economic policy.

Standards and Benchmarks

Voluntary National Content Standards in Economics

Standard 2: Decision Making

Effective decision making requires comparing the additional costs of alternatives with the additional benefits. Many choices involve doing a little more or a little less of something: few choices are "all or nothing" decisions.

Standard 4: Incentives

People usually respond predictably to positive and negative incentives.

Common Core State Standards

CCSS.ELA-Literacy.RH.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.

Note

MacGill, Markus. "Polonium-210: Why Is Po-210 So Dangerous?" *Medical News Today*, updated July 28, 2017; http://www.medicalnewstoday.com/articles/58088.php.