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LESSON:

Ports in a Storm: A Surge of Solutions

Summary: Students read about the various environmental health issues related to ports and the shipping industry. As a class, students generate a systems model related to the ship-salvaging industry. Then in small groups, students create their own systems model for a specific solution to decrease emissions from ships at or near ports.

EHP Article: "Ports in a Storm"
EHP Student Edition, July 2006, p. A222–A231
http://www.ehponline.org/members/2006/114-4/focus.html

Objectives: By the end of this lesson, students should be able to:

1. identify environmental health issues related to ports and shipping;
2. communicate about the complexity of systems and cause/effect relationships;
3. identify the difference between direct and indirect effects of an action; and
4. identify the difference between short-term and long-term effects of an action.

Class Time: 6–7 hours

Grade Level: 11–12

Subjects Addressed: General Science, Environmental Science, Economics, Social Studies

Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire July 2006 *EHP Student Edition* at http://www.ehponline.org/science-ed/, or download just the article "Ports in a Storm" at http://www.ehponline.org/members/2006/114-4/focus.html.
2. Review the Background Information, Instructions, and Student Instructions.
3. Make copies of the Student Instructions.

MATERIALS (per student):

- 1 copy of *EHP Student Edition*, July 2006, or 1 copy of "Ports in a Storm," preferably in color
- 1 copy of the Student Instructions

VOCABULARY:

- flow chart
- system dynamics
- systems thinking

BACKGROUND INFORMATION:

The article provides sufficient background information on the variety of environmental health issues associated with ports; here we discuss the approach taken for the lesson. The activity you will be modeling with students as a class, and then asking them to conduct independently in small groups, is called "system dynamics" or "systems thinking."

MIT engineer Jay Forrester is credited as the father of system dynamics (http://www.systemdynamics.org/). In the 1961 book *Industrial Dynamics*, he showed the need and methods for modeling complex systems to solve problems. System dynamics is a process that considers inputs and outputs or causes and effects within a system, including feedback loops within that system. The concept holds that to truly understand and be able to solve a problem, you need to be aware of the greater context for the problem, as well as the cascading events that may occur when change is implemented. This is contrasted with a more linear approach where problems are isolated, ideas for solutions are generated, and solutions are selected with little consideration of the other potential effects of implementing that solution. Often linear decisions are made with respect to consideration of the immediate direct effect (e.g., profits will be impacted), rather than long-term or indirect effects (e.g., impact on public health).

The example from the article that you will complete with students is to generate a flow chart showing the system dynamics related to ship salvaging. Some of the information to create the flow chart model is included in the article, but other aspects of the model will be generated through dialogue with the students. It will take some time to develop the flow chart with the class, but this is an important step to show students the kinds of considerations that are involved in generating a system dynamics model.

Note that the model may start to get messy, and revisions are likely to occur along the way in order to visually connect the pieces in the most representative fashion. Let students know this is fine and a natural part of the process. Also, you may have to revisit the "flow" in order to remember where you were headed. Again, this is natural because what you are creating is inherently complex. Another aspect to keep in mind is that the middle of the system dynamics process can potentially feel overwhelming as it often "balloons" into large-scale, global effects like civil unrest or even war. To minimize the feeling of being overwhelmed, work with one piece at a time and revisit the original problem after some of the details are in place.

When creating their own models, some students may become frustrated with the process, so continue to encourage and guide them. The completion of a system dynamics model is very rewarding for students because they can develop a whole new perspective, seeing the problem as a "whole" and identifying potential solutions that can have a significant, long-lasting impact. Admittedly, some of the initial solutions appear at first to be on a seemingly impossible "save the world" scale, but at this point students should be encouraged to work backwards from the "global solution" to the "local solution." This allows them to envision a realistic path and, with one step at a time, the "impossible" becomes possible. By doing this activity, students can understand the real meaning behind clichés like "think globally, act locally" and "a journey of a thousand miles begins with one step."

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov. Choose Industry Issues, Waste Disposal

Hricko AM. Ships, trucks, and trains: effects of goods movement on environmental health [editorial], http://www.ehponline.org/docs/2006/114-4/editorial.html

System Dynamics Society, http://www.systemdynamics.org/

Implementing the Lesson

INSTRUCTIONS:

1. Hand out the article "Ports in a Storm."
2. As a class, read the article aloud through page A228, to the subheading "Not There Yet." During the reading take notes with the class on the board to highlight key information.
3. Tell the students they will finish reading the article later when they are divided into groups, and that they will be assigned one of the scenarios for reducing emissions at ports described at the end of the article. For their scenario, the students will generate a flow chart showing factors and if/then scenarios related to their issue. In order to familiarize the students with the process, take them through the following system dynamics example. You may want to take a moment to briefly introduce system dynamics to the students.
   a. Begin by identifying an example issue from the article (ship salvaging), then ask students to provide their ideas for advantages and disadvantages to ship salvaging. Note: Some of the items included in the flow chart are not explicitly listed in the article, but are "common sense." The goal of this exercise is to get the students to think about as many connected factors as possible, hypothesize about cause/effect, and generate an understanding of systems complexity.

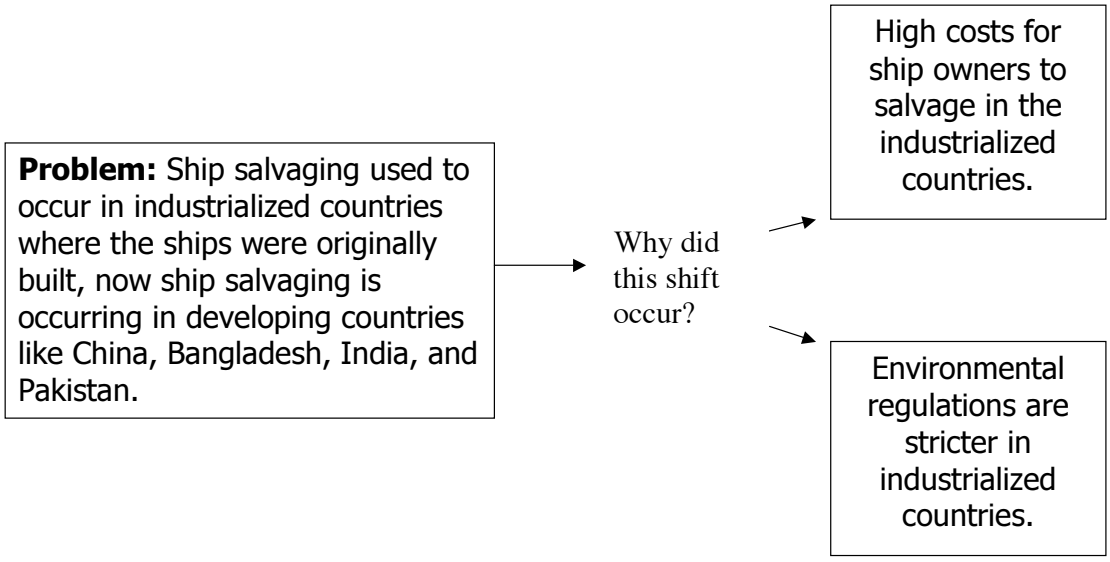
      ISSUE: Ship Salvaging

      Advantages: recycling; ship owner may recoup some money from old ships

      Disadvantages: high worker injury; toxic chemicals/asbestos are on many of the ships

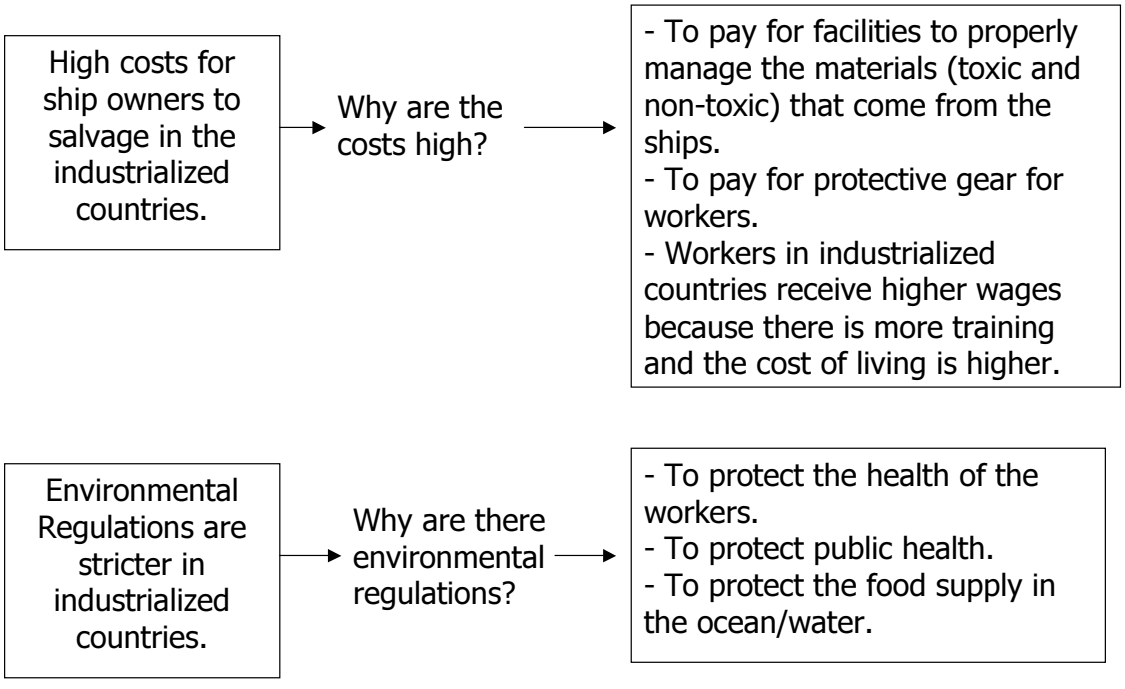
   b. Start creating a flow chart with the students. As a starting point, use the problem of irresponsible ship salvaging and why it is occurring (see Flow Chart 1).

Flow Chart 1



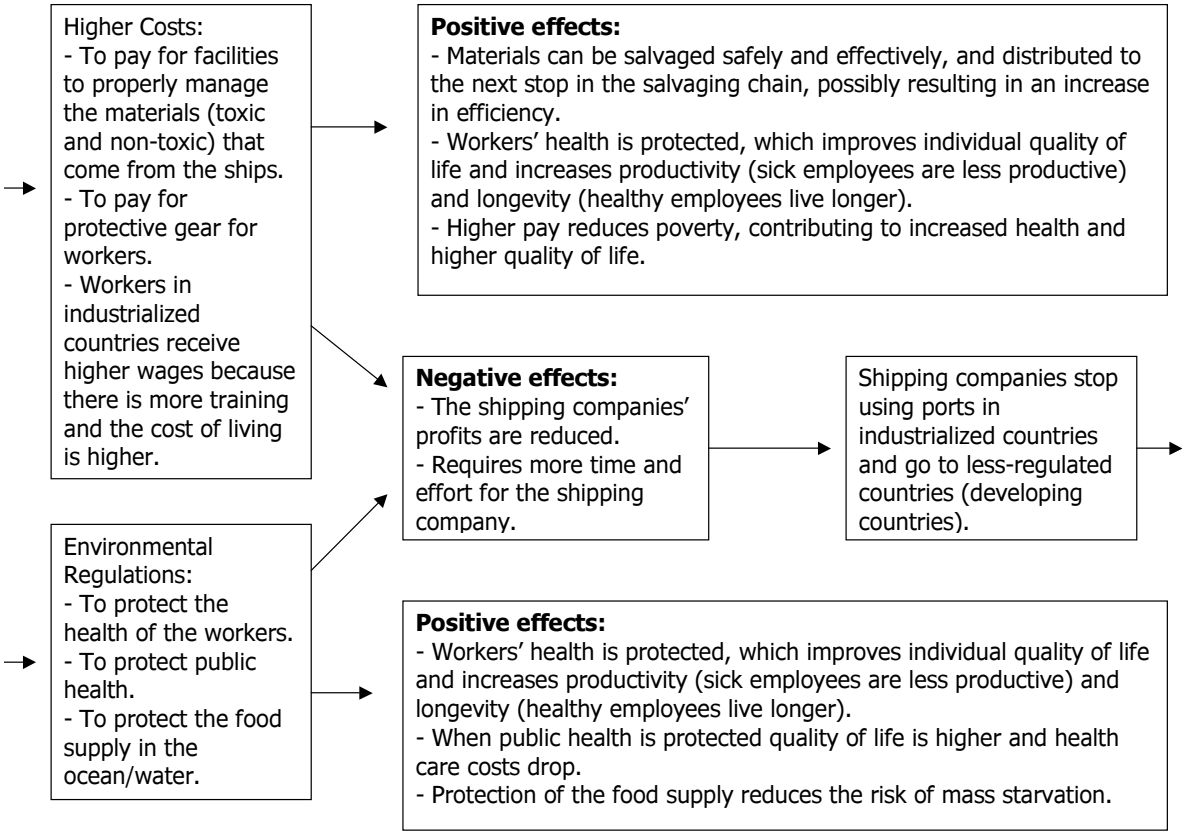
c. Now have students identify potential consequences of the high costs and the environmental regulations (Flow Chart 2). Ask questions like: "What do you think the high costs of ship salvaging in industrialized nations pays for?" "Why do you think the environmental regulations were put into place?" Write down the answers. (Note: For space-saving reasons, only the piece of the flow chart being directly discussed will be shown here. The flow chart you draw on the board can be drawn in pieces, but eventually should include all six of the flow charts.)

Flow Chart 2



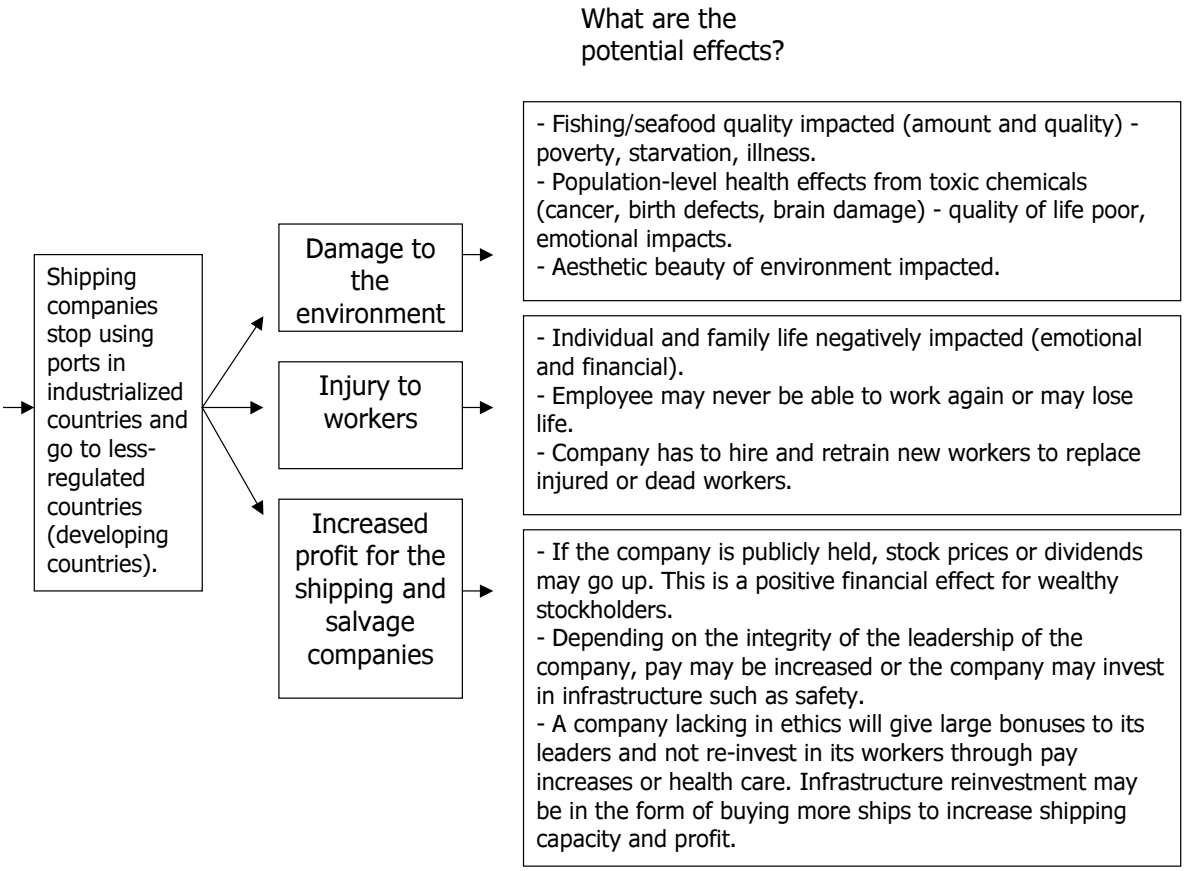
d. Have students provide examples of positive and negative effects from the high salvaging costs and environmental regulations (Flow Chart 3). When discussing the negative effects we are led back to the original problem of ship salvaging moving to countries that have fewer regulations. The next step will be to focus on the issues related to that problem.

Flow Chart 3



e. Some of the issues related to the problem of shipping companies going to less-regulated countries include negative environmental impacts, injury to workers, and increased profits for companies. Solicit examples of potential effects for each of these. Refer to Flow Charts 4, 5, and 6 below to guide the conversation. Continue to ask the question "What are the potential effects" until the students arrive back at the original problem, which was increased costs and environmental regulations pushing shipping companies toward developing countries with fewer regulations.

Flow Chart 4


What are the potential effects?
Shipping companies stop using ports in industrialized countries and go to less-regulated countries (developing countries).
Damage to the environment
Injury to workers
Increased profit for the shipping and salvage companies
- Fishing/seafood quality impacted (amount and quality) - poverty, starvation, illness.
- Population-level health effects from toxic chemicals (cancer, birth defects, brain damage) - quality of life poor, emotional impacts.
- Aesthetic beauty of environment impacted.
- Individual and family life negatively impacted (emotional and financial).
- Employee may never be able to work again or may lose life.
- Company has to hire and retrain new workers to replace injured or dead workers.
- If the company is publicly held, stock prices or dividends may go up. This is a positive financial effect for wealthy stockholders.
- Depending on the integrity of the leadership of the company, pay may be increased or the company may invest in infrastructure such as safety.
- A company lacking in ethics will give large bonuses to its leaders and not re-invest in its workers through pay increases or health care. Infrastructure reinvestment may be in the form of buying more ships to increase shipping capacity and profit.

Flow Chart 5

What are the potential effects?

- Fishing/seafood quality impacted (amount and quality) - poverty, starvation, illness.
- Population-level health effects from toxic chemicals (cancer, birth defects, brain damage), quality of life poor, emotional impacts.
- Aesthetic beauty of environment impacted.

- Individual and family life negatively impacted (emotional and financial).
- Employee may never be able to work again or may lose life.
- Company has to hire and retrain new workers to replace injured or dead workers.

- If the company is publicly held, stock prices or dividends may go up. This is a positive financial effect for wealthy stockholders.
- Depending on the integrity of the leadership of the company, pay may be increased or the company may invest in infrastructure such as safety.
- A company lacking in ethics will give large bonuses to its leaders and not re-invest in its workers through pay increases or health care. Infrastructure reinvestment may be in the form of buying more ships to increase shipping capacity and profit.

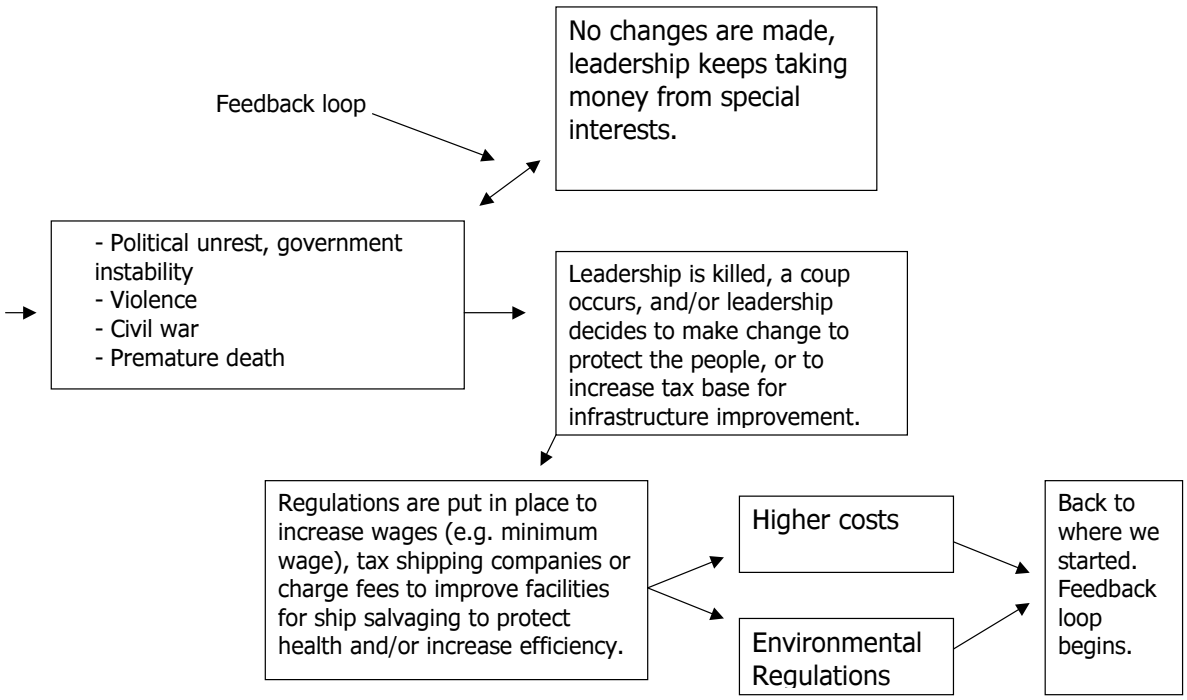
- Political unrest, government instability
- Violence
- Civil war
- Premature death

- Large amounts of money can get concentrated into the hands of a few people.
- Money can be used to "buy out" leaders of countries and influence policy to keep company profits high at the expense of the workers, environment, and taxpayers.

- When companies expand, more jobs are created.
- When companies share profits with their employees, health, wellness, and productivity increase.
- When employees have pay increases they have more money to spend, which spreads the wealth into other sectors, expanding the economy.

f. For Flow Chart 6 we focus on the political unrest, because there is more to be explained or inquire into:

Flow Chart 6



g. Initiate a discussion with the students to address the following questions:
   - In the worst-case scenarios, we have ended up with violence and civil war. Does this seem like a feasible outcome considering the logic we used? If one of us said ship-salvaging activities could potentially lead to violence, political unrest, and civil war, would you have believed it prior to doing this activity? Do you see violence and civil war really happening in the world? What are the factors that contribute to such unrest?
   - What happens to a society or country as a result of the cycle of poverty, violence, and civil unrest?
   - What happens when a government or society decides to protect its people?

h. Ultimately this series of questions leads us back to the original problem, which was ship-salvaging companies going to developing countries to avoid environmental regulations. Eventually, if countries reach similar points where they decide to protect their people and enact health-protective legislation, there will be fewer unregulated places ship-salvaging companies can go. Other economic factors will then take over and drive the business in different directions.

4. Instruct the students to read the section of the article titled "Regulatory and Technology Issues" on pages A230–A231. (In order to save time and focus on sections of the article that directly relate to the activity, you may consider skipping the section titled "Not Yet There" on pages A229–A230). Students should highlight factors they feel are important, as well as possible solutions to the emissions problems.
5. After the students have finished reading the last section, ask them to provide ideas for ways to reduce emissions. The list should include these concepts:
   - Develop technologies that increase efficiency (e.g., go farther on the same amount of fuel so that less fuel is burned in the same time period) and reduce emissions.
   - Develop fuels that burn cleaner (produce less sulfur products).
   - Have ships plug into electrical outlets at the ports, rather than running their engines.
   - Move ports away from population centers.
   - Decrease ship speed as they approach the port.
6. Divide the students into groups of three, assigning each group one of the ideas for emissions reduction listed above. Depending on your class size, some groups will have the same topic. This is OK because when the students present their flow chart to the rest of the class, groups with the same topic may have different ideas to share.

7. Hand out the Student Instructions and review them as needed. Inform the students that their flow charts will be simpler than the example you went through in class and may not be as broad-reaching or all-encompassing. The Assessing the Lesson section provides examples of factors to consider for the emissions reduction scenarios. Refer to the Assessing the Lesson section as needed to help students along in the process.
8. After each group's flow chart is completed, have the groups present their work. Discuss similarities and differences between the issues addressed in the flow charts.
9. As a class, vote on which emissions reduction idea they think is the best or which one should be implemented first. Is a combination of solutions best? What about short-term versus long-term effects? There is no right or wrong answer, just ask the students to justify their answer. See if the class can reach a consensus. Ask them how their ability or inability to reach a consensus reflects what is going on in the "real world" with respect to controlling emissions at ports.

NOTES & HELPFUL HINTS:

- Another possible emissions reduction solution that is not explicitly mentioned in the article is to reduce the demand side of the equation (e.g., stop buying throw-away junk toys). You may want to discuss this option as a class, or create another class-developed flow chart, after the students have completed their group presentations.

SKILLS USED OR DEVELOPED:

- Classification
- Communication (oral, written—including summarization)
- Comprehension (listening, reading)
- Critical thinking and response
- Manipulation
- Observation
- Tables and figures (creating, reading)
- Technological design

SPECIFIC CONTENT ADDRESSED:

- Environmental health issues for ports and shipping
- System dynamics
- Systems thinking
- Emissions control

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Evolution and equilibrium

Science As Inquiry Standard

- Abilities necessary to do scientific inquiry

Life Science Standard

- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

Science and Technology Standard

- Abilities of technical design
- Understanding about science and technology

Science in Personal and Social Perspectives Standard

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Assessing the Lesson

This section provides lists of issues and factors that relate to each emissions reduction idea presented in this lesson. Use this section as a reference during grading. Please note that the factors and causes/effects are compressed in these answers in order to save space. Students should not lump issues together but instead separate them out into sequential if/then scenarios separated by arrows. Students may generate different examples than provided here. Design of the flow chart may vary from group to group.

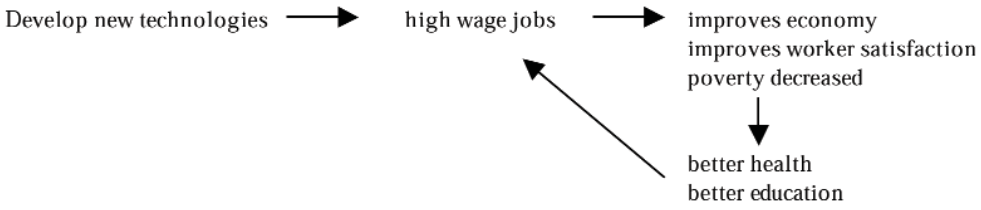
The key aspects to look for in the overall flow chart include:

- Is the flow chart logical, or are there major gaps?
- Are enough details provided to follow the flow of logic?
- Are the main points and issues of the problem/solution addressed in the flow chart?
- Have the students provided details or ideas that demonstrate critical analysis and cause/effect?
- Did the flow chart reach a logical end point or get as far as a large-scale feedback loop?
- When the students present, is their information clear?
- Did all of the students in the group contribute?

Example considerations for options for reducing emissions:

1. Develop technologies that increase efficiency (e.g., go farther on the same amount of fuel so that less fuel is burned in the same time period) and reduce emissions.
   - The development of new technologies generates high-wage jobs and decreases poverty, which benefits individuals and raises the economy; it also improves worker satisfaction, which increases health and education levels.

     The flow for this factor would look something like:



   - New technologies can be expensive, which reduces the shipping company's profit. The shipping company may try to cut costs by not providing health insurance, by paying lower wages, or by cutting corners somewhere else or raising prices, which gets passed on to the consumer (inflation).
   - New technologies could be used in a variety of machinery that generates emissions at ports (e.g., cranes), resulting in a potentially greater reduction of emissions overall (compared to just reduction of ship emissions).
   - Unless enforceable regulations are put into place to require the use of new technologies, it could take many years before old, dirty technology is phased out (i.e., it eventually stops working and has to be replaced).
2. Develop fuels that burn cleaner (produce less sulfur products).
   - Companies that make the fuels have to invest in the labor and brain power to figure out how to generate cleaner fuels and buy new machinery to produce the new fuel. This decreases the fuel companies' profits, so they will likely raise prices to make up the difference.
   - Shipping companies will have to pay higher prices, which decreases their profits, so they will either cut costs or raise prices, which ultimately gets passed on to the consumer (inflation).
   - Even with cleaner-burning fuels, emissions will still be a problem because the older fuel-burning technology is not efficient.

3. Have ships plug into electrical outlets at the ports, rather than running their engines.
   - Shipping companies may have to pay more to plug in, compared to running their engine. However, this depends on fuel costs. If the plug–in cost is lower than the cost to run the engine and burn the fuels, then the shipping company profits are increased.
   - Plugging in reduces noise pollution along with emissions, benefiting the workers and people who live nearby.
   - Plugging in still generates emissions if the electricity comes from a coal-fired power plant. However, if alternative forms of energy, such as wind, generate the electricity, this is a viable option.
4. Move ports away from population centers.
   - This still creates emissions that can be spread around the world, but does not have the immediate impact to humans living nearby.
   - Unless zoning restrictions are put into place to prevent housing from being built nearby, communities may grow where the work is.
   - Port workers are still being exposed to emissions.
   - Work locations far away from communities where people live results in increased emissions from traveling to work. This impact can be reduced by public transportation or having workers stay in overnight facilities at the port, which raises construction expenses to build the facilities.
5. Decrease ship speed as they approach the port.
   - This increases the amount of time it takes for ships to deliver their load, which costs more money in terms of paying people for more of their time, and there is a delay in receiving payment for shipping. If loans are being paid off by the shipping company and payments for their services are delayed, they may end up paying more interest on the loans, or receiving less interest on money that would have been in the bank. The net result is higher costs for the shipping company.
   - Slower speeds may make scheduling ships' arrivals into port more challenging or complex. The port may need to expand to accommodate more ships or the time delays may slow the payments from the shipping companies to use the ports. Expanding ports could bring in new jobs, injecting money into the economy. Expanding ports result in higher costs, which may result in cost-cutting efforts by the ports (cutting jobs, no health care, decreased wages) or increases in prices. If port infrastructure is subsidized by taxpayers, this may result in higher taxes. Higher taxes reduce the net income of the people. However the cost of increased taxes is probably much less than the cost of health care expenses from exposure to emissions.
   - Slowing speed may use less fuel in the long run, which could save the shipping company money.

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Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.

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STUDENT INSTRUCTIONS: Ports in a Storm: A Surge of Solutions

Step 1: As a class, read the first part (pages A223–A228) of the article "Ports in a Storm." Be sure to participate in the discussion led by your teacher.

Step 2: Read the remaining section of the article titled "Regulatory and Technology Issues," pages A230–A231. (You may or may not be asked by your teacher to read the section titled "Not Yet There" on pages A229–A230.)

Step 3: Divide into groups of three students each. Your teacher will assign you one option for reducing emissions from shipping. In your group, you will identify factors and cause/effect relationships associated with your emissions reduction option. You can think of it like a domino effect: that one event sets off a series of other events.

Present these factors and cause/effect events in a flow chart format (like the ship-salvaging model you created as a class). Creating a model shows the "flow" and connection between things that may have otherwise seemed independent. Consider the following questions at each stage of your model, then show the answers in your model (e.g., in a square or circle connected by arrows).

- What are the positive and negative impacts of that item or issue?
- Why?
- What are the potential effects of that item or issue?

You will be graded on the following:

- Is the flow chart logical, or are there major gaps?
- Are enough details provided to follow the flow of logic?
- Are the main points and issues of the problem/solution addressed in the flow chart?
- Has your group provided details or ideas that demonstrate critical analysis and cause/effect?
- Did the flow chart reach a logical end point or get as far as a large-scale feedback loop?
- When your group presents, is your information clear?
- Did all of the students in your group contribute?

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