Build a Natural Gas Pipeline

Subjects	Science, Language Arts, CTE
Duration	Preparation: 10 minutes | Activity: 40 - 60 minutes, may be split over multiple days
Setting	Classroom
Objectives	1. Define a simple design problem to build a model natural gas pipeline with specified criteria and constraints. 2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints. 3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of the model that can be improved. 4. Write a summary describing how the group analyzed the problem, the solution to the problem decided upon, and the results of testing with suggestions for improvement. 5. Create a visual or audio public service announcement that includes the following topics: safety rules and regulations regarding transmission of natural gas in pipelines as well as mercaptan, signs of a natural gas leak, what to do and what not to do if you suspect a natural gas leak.

Materials

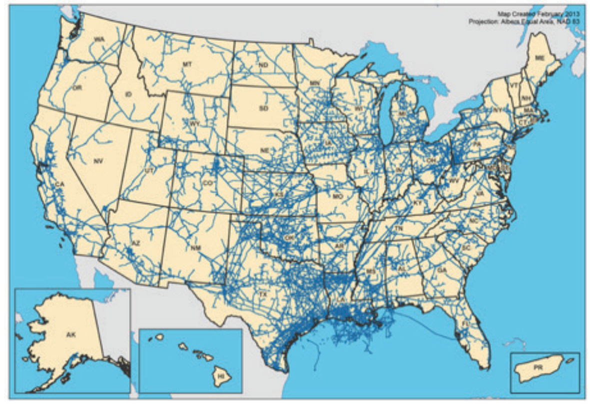
- Copies of the student sheet
- Goggles for each student
- One container to hold model per group
- 60 mL per group (equal to 12 teaspoons or 4 tablespoons) of vinegar solution, dyed blue
- Needleless syringe, 60 mL is optimal (may be shared among groups if disinfectant cleaning is used)
- Small water balloons
- Four bendable straws per group
- Measuring scoop or spoon (may be shared among groups if disinfectant cleaning is used)
- 5 mL baking soda (equal to 1 teaspoon)
- Sand or soil to fill containers to a depth of one inch (amount depends on the container chosen)
- Masking tape and other adhesives such as duct tape or electrical tape
- Low temperature glue guns (may be shared among groups if disinfectant cleaning is used)
- Glue sticks, average two per group
- Rulers
- Scissors
- Other materials of your choice students may find useful in connecting the straws or holding them in place

Scientific Terms for Students

- City gate: As a pipeline nears a city, some natural gas is diverted through the city gate where its pressure is reduced and it is measured and sold to the local natural gas company. Mercaptan is added by the gas company at the city gate. From the city gate or other distribution pipelines, the natural gas company distributes the natural gas through an underground network of smaller pipelines.
- Mains: Underground pipelines that connect city gates to smaller pipes that go to individual buildings

Educator Background

Natural gas is delivered to North American consumers through a network of underground pipes 3 million miles long. As natural gas leaves the processing plant, it enters a compressor station where it is pressurized. As natural gas flows through the pipeline, it rubs against the inside walls of the pipe and the friction reduces the pressure and slows the gas. This loss of pressure is made up at compressor substations every 50 to 100 miles. Valves are used to control pressure and cut off flow in an emergency such as a break in the line or a fire. Distributors add a stinky chemical called **mercaptan** to the purified natural gas so a leak can be detected.



The US natural gas pipeline system stretches over two million miles, connecting to pipelines in Canada and Mexico.
(Map courtesy of the U.S. Energy Information Administration.)

Transmission pipelines may be as large as 56 inches in diameter, but most are 20 to 30 inches. The diameter is largely a function of the "peak demand," which is set by the number of users and the time of year. The pipes must be large enough to handle sufficient quantities of natural gas to meet the needs of consumers during the high peak use periods – typically the winter months when natural gas heating drives up usage.

As a pipeline nears a city, some natural gas is diverted through a **city gate**, where its pressure is reduced, and it is measured and sold to the local natural gas company. From the city gate or other distribution lines, the natural gas company distributes the natural gas through an underground network of smaller pipelines called **mains**. Still smaller pipes connect the mains directly to end users – homes, schools and businesses. There, the natural gas flows through meters which measure the exact amount of natural gas used and the natural gas company bills the user. Learn more at ***ingaa.org***, the website for the Interstate Natural Gas Association of America.

Instructor Prep

1. Print the "Build Natural Gas Pipeline Student Sheet" for each student group.
2. Collect the materials listed for student use, plus a small funnel.
3. Using the funnel and a measuring spoon, scoop 5 mL (1 teaspoon) of baking soda into enough water balloons for each student group, plus a couple of extras in case of breakage.
4. Caution: Because vinegar is used, goggles should be worn to protect eyes in case of leakage at the balloon or while inserting vinegar into the straw with the syringe.
5. Optional – place about an inch of sand in each group's container to save time.

Activity Procedure: Part One

1. As a group, brainstorm what a gas company has to consider when deciding where to put pipelines. *Some factors include materials costs, labor costs, environmental impact and safety concerns.*
2. Pass out the student sheets.
3. Have students use the sheet to decide where they would place a natural gas pipeline to connect the house to the city distribution line. They need to consider the factors from your brainstorming session. Each square they pass through has a cost based on what is in the square.
4. When the groups are finished, discuss the results. Relate this exercise to economics and opportunity costs.

Activity Procedure: Part Two

1. Explain to students that they will be pipeline workers trying to connect a new home to the city gate. They must work within the following constraints:
    a. The pipeline must make two turns to get to the gate, one to turn the pipe down into the earth and one to turn it sideways to meet the pipe at the house.

b. They cannot use more than four straws.
c. They must budget $200 for each half inch of straw that they use.
d. The gate is on one end of the container you will provide. It must have a straw section that sticks straight up for injection of the natural gas.
e. The house is on the opposite side of the container and will be represented by a water balloon with 5 mL of baking soda placed inside of it.

2. Give student groups a container with a thin layer of sand, a ruler, a marker, four bendable straws, a piece of graph paper and a water balloon. If you want to make the activity more challenging, add obstacles such as trees, a modeling clay pond, etc.
3. Have students look at the adhesives and other materials you have available and decide which items they would like to use to connect their straws and secure them. They can use any of the materials you have provided, but only four straws.
4. Give students time to work on a solution to the problem.
5. Before students actually build the pipeline, they should measure the length of one of their straws to the nearest half inch. This distance should be multiplied by four to get the total number of half inches of pipe they have. Remember that they will be charged by the half inch.
6. Have students build their pipeline, keeping all of the unused straws and straw pieces. They will use them at the end.
7. Test the pipelines by having students:
    a. **Wear goggles at all times when handling vinegar solution to protect eyes.**
    b. Connect the water balloon with baking soda to the house side of the container.
    c. Provide them with a container of blue vinegar water and a syringe.
    d. Have students prop the container up on a book at the city gate end. Gravity will take the place of the pressure in a real natural gas pipe. All groups need to use the same book thickness, so a textbook works well.
    e. Have students fill the syringe all the way to the top, then inject the vinegar water into their straw at the city distribution line.
    f. If the test is successful, the liquid will reach the balloon. If there are leaks, they should be obvious based on both the blue color and the odor of the vinegar. This is similar to how we can find leaks in a real gas pipeline.
8. When the groups are finished testing, you can allow them to modify their designs, but they cannot have any more straws.
9. After all testing is complete, each group should use the ruler again to find the total number of half inches of straw they have leftover. To find the price of their pipeline, they subtract this number from the starting total and multiply the answer by 200.
10. Discuss the results. What materials were best to hold the straws in place? What materials were best to join straws together? Have students share the cost of their pipeline. How could/did students improve their results?

Wrap-up

- Have students write a paragraph on how the group analyzed the problem, the solution to the problem decided upon and the results of testing with suggestions for improvement.
- Have students work in groups to create a visual or audio public service announcement about natural gas safety including topics such as safety rules and regulations regarding transmission of natural gas in pipelines, mercaptan, signs of a natural gas leak, what to do and what not do to if you suspect a natural gas leak.
- Use the U.S. Energy Mapping System to see how Indiana pipelines connect to the rest of the nation

and discuss how Indiana is interdependent with other states.

Extensions

- Do the “Pipelines in your Neighborhood and Contacting 811” activity if you have not already done so to explore how natural gas is transported safely to millions of homes and businesses in Indiana.

Science Standards Addressed

SCIENTIFIC & ENGINEERING PRACTICES

Developing and Using Models

Modeling in 9 – 12 builds on K – 8 and progresses to using, synthesizing and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2), (HS-PS3-5)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9 – 12 builds on K – 8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements consider limitations on the precision of the data (e.g., number of trials, cost, risk, time) and refine the design accordingly. (HS-PS3-4)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9 – 12 level builds on K – 8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create a computational model or simulation of a phenomenon, designed device, process or system. (HS-PS3-1)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9 – 12 builds on K – 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.

- Design, evaluate and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations. (HS-PS3-3)

DISCIPLINARY CORE IDEAS

HS-ETS1-A Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

HS-ETS1.B. Designing Solutions to Engineering Problems

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability and aesthetics, and to consider social, cultural and environmental impacts. (secondary to HS-ESS3-2, secondary to HS-ESS3-4)

CROSS CUTTING CONCEPTS

Influence of Science, Engineering, and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS2-2)

Related Standards

SCIENCE AND TECHNICAL SKILLS STANDARDS

CCSS.ELA-LITERACY.RST.9-10.1

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CCSS.ELA-LITERACY.RST.9-10.3

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements or performing technical tasks, attending to special cases or exceptions defined in the text.

References

NaturalGas.org, *naturalgas.org/naturalgas/distribution*

EIA, *eia.gov/kids*

Interstate Natural Gas Association of America, *ingaa.org*

Build a Natural Gas Pipeline, Part One

In this activity, you will:

1. Design a solution to a problem with specified criteria and constraints.
2. Compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints.
3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of the model that can be improved.

Vocabulary

- City gate: As a pipeline nears a city, some natural gas comes through the city gate where its pressure is reduced and it is measured and sold to the local natural gas company.
- Mains: Underground pipelines that connect city gates to smaller pipes that go to individual buildings

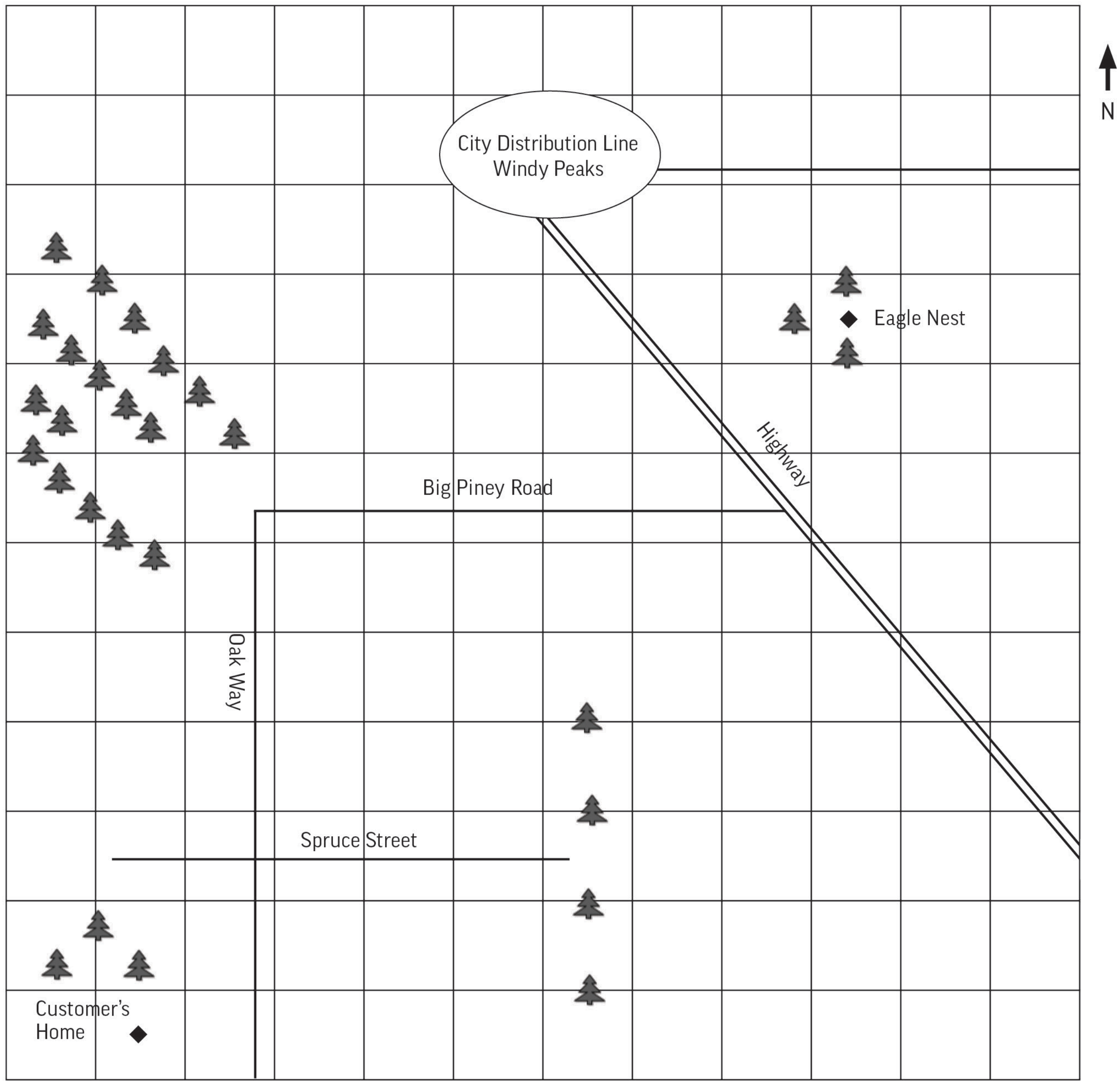
Procedure

1. Examine the pipeline grid map and rules on the next page.
2. Using a pencil, mark three possible paths for a pipeline to connect the house to the city gate.
3. Determine the cost of each path below:

Count	**Path 1**	**Path 2**	**Path 3**
Number of squares the pipe passes through			
Number of times the path disturbs trees			
Number of times the path crosses a road			
Cost			
$200 x each square crossed =			
$200 x each square with trees =			
$300 x each time road is crossed =			
Total Cost (add the three rows above) =			

4. Based on the cost and your class discussion, pick the path you will use and trace it with a marker on the grid map.
5. Which path did you choose (1, 2 or 3)? ___________
6. Did anything other than cost influence your choice? ___________ What other things did you consider in making your choice?

Pipeline Grid Map **1 square = 1000 feet = costs $200 to lay pipe**



Pipeline Rules:

- The gas pipeline must go from the city gate and to the customer's house.
- Pipes can only run side to side and up and down, not diagonally.
- If your pipe goes through **any** part of a square, you have to pay for that square.
- Anytime you pass through a square with trees it costs an extra $200. Anytime you pass under a road square it costs an extra $300.
- If you disturb the eagle nest, there will be protests from many customers.

Build a Natural Gas Pipeline, Part Two

In this part of the activity you are pipeline workers connecting a new home to the city gate.

Procedure:

1. Get these materials from your teacher: goggles, a container, a syringe, a spoon, a ruler, two pieces of masking tape and four bendable straws. Find out where you can get sand if it is not already in your container.
2. Put a layer of sand in the box about an inch deep if it is not already done for you.
3. On one piece of tape, write City Distribution Line. On the other write HOUSE. Place the pieces of tape at opposite ends of your container.
4. Measure the length of one straw with your ruler and record it here. ____________
5. You must work within the following constraints:
   a. The pipeline must make two turns to get to house from the city gate, one to turn the pipe down into the earth at the gate and one to turn it sideways to meet the pipe at the house.
   b. You cannot use more than four straws.
   c. You must budget $200 for each half inch of straw used.
   d. The city gate side of the container must have a straw section that sticks straight up for injection of the natural gas.
   e. The house is on the opposite side of the container, and will be represented by a water balloon with 5 mL of baking soda placed inside of it.
   f. The pipe cannot leak natural gas into the environment.
6. With your group, decide how you will join your straws together to reach from the city gate to the house. Look at the materials your teacher has provided and make a plan.
7. Build your pipeline, saving all the straw pipe pieces. If you have extra pieces of pipe leftover, that is money you have saved.

   Caution: Because vinegar is used, goggles should be worn to protect eyes in case of leakage at the balloon or while inserting vinegar into the straw with the syringe.

   Hints: inject some of the "natural gas" fluid into your pipeline before connecting the balloon. Squeeze as much air as you can out of the balloon before connecting it.

Questions

1. Track the money you are spending on pipelines and total it below:

   Number of half inches of pipe to start with ____________
   -
   Number of half inches of pipe leftover ____________

   Total length of pipe used in half inches = ____________ x *$200 =* ____________
2. Did your design work the first time, or did it leak?
3. How could you improve your results?