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Lesson Focus

Lesson focuses on how engineers develop pipeline systems to transport oil, water, gas, and other materials over very long distances. Lesson provides background about three major pipeline systems worldwide. Students work in teams of "engineers" to develop a pipeline system to transport both a golf ball and ping pong ball across the classroom terrain. Teams develop a plan, draw their pipe plan, anticipate part requirements, build their pipeline, evaluate other plans, and reflect on the activity.

Lesson Synopsis

The Pipeline Challenge activity explores how engineers work in a team to solve problems, such as planning a pipeline to deliver water, oil, or gas to a community. Students learn how land and weather, distance, and materials to be transported impact engineering plans. Students work in teams to design a pipeline to transport both a golf ball and ping pong ball from one end of the classroom to another with obstacles and turns. Students develop a plan/drawing, execute their pipeline plan, and evaluate the strategies employed by other student teams.



Age Levels

8-18.

Objectives

- ◆ Learn how civil engineers approach large scale problem solving.
- ◆ Learn how engineering teams address problem solving.
- ◆ Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- ◆ engineering design
- ◆ problem solving
- ◆ teamwork

Pipeline Challenge

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Lesson Activities

Students learn how land and weather, distance, and materials to be transported impact engineering plans. Students work in teams of "engineers" to design a pipeline to transport both a golf ball and ping pong ball from one end of the classroom to another with obstacles and turns. Students develop a plan/drawing, execute their pipeline plan, and evaluate the strategies employed by other student teams.

Resources/Materials

- ◆ Teacher Resource Documents (attached)
- ◆ Student Worksheets (attached)
- ◆ Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- ◆ TryEngineering (www.tryengineering.org)
- ◆ PBS Learning: Building the Alaska Oil Pipeline (<https://mpbn.pbslearningmedia.org/resource/ean08.sci.ess.earthsys.pipeline/building-the-alaska-oil-pipeline/>)

Recommended Reading

- ◆ Oil & Gas Pipelines in Nontechnical Language (ISBN: 159370058X)
- ◆ Piping and Pipeline Engineering: Design, Construction, Maintenance, Integrity, and Repair (ISBN: 0824709640)

Optional Writing Activity

- ◆ Write an essay or a paragraph describing how the impact on the environment must be considered when developing a new pipeline system. Give examples of a pipeline in your country that had environmental implications.

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For Teachers: Teacher Resource

◆ **Lesson Goal**

Explore engineering problem solving by working in teams to determine a plan for a classroom pipeline. Lesson focuses on how engineers develop pipeline systems to transport oil, water, gas, and other materials over very long distances. Students work in teams of "engineers" to develop a pipeline system to transport both a golf ball and ping pong ball across the classroom terrain. Teams develop a plan, draw their pipe plan, anticipate part requirements, build their pipeline, evaluate other plans, and reflect on the activity.

◆ **Lesson Objectives**

- ◆ Learn how civil engineers approach large scale problem solving.
- ◆ Learn how engineering teams address problem solving.
- ◆ Learn about teamwork and working in groups.

◆ **Materials**

- ◆ Student Resource Sheets and Worksheet
- ◆ One set of materials for each student group:
 - Golf ball (or similarly sized rubber ball), ping pong ball
 - Piping set up (assuming a 15' x 15' room, allow for about 20 feet of cardboard or PVC tubing. These can be found in paper towel or toilet paper rolls using two rolls of strong plastic packing tape for connections. Angled pieces can be cut for the required turns.)



◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students, providing a set of materials per group.
3. Explain that they are engineering teams that have been hired to design and test a pipeline to carry a golf ball and a ping pong ball across your classroom. The successful design will include four angles including one right angle (90 degrees), and a height difference of no more than 18 inches from the beginning to the end of the pipeline. Be sure to identify environmentally protected areas, water, or other hazards in your classroom that the students will have to consider in their plan.
4. Student teams develop the shape of their pipeline on paper, then build their pipeline with materials provided.
5. Each student group evaluates the pipelines developed by other teams, and completes an evaluation/reflection worksheet.

◆ **Time Needed**

Two to four 45 minute sessions

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Student Resource

Pipeline Projects and Facts

Pipeline transport is a transportation of goods through a pipe. Most commonly, liquid and gases are sent, but pneumatic tubes that transport solid capsules using compressed air have also been used. As for gases and liquids, any chemically stable substance can be sent through a pipeline. Therefore sewage, slurry, and water pipelines exist; but arguably the most important are those transporting oil and natural gas.

◆ Baku-Tbilisi-Ceyhan Pipeline

The Baku-Tbilisi-Ceyhan pipeline (sometimes abbreviated as BTC pipeline) transports crude petroleum 1,776 km from the Azeri-Chirag-Guneshli oil field in the Caspian Sea to the Mediterranean Sea. The total length of the pipeline in Azerbaijan is 440 km long, in Georgia it is 260 km long and in Turkey is 1076 km long. There are 8 pump stations through the pipeline route. The construction of the BTC pipeline was one of the biggest engineering projects of the last decade. It was constructed from 150,000 individual joints of line pipe, each measuring 12 m (39 ft) in length. It has a projected lifespan of 40 years, and when working at normal capacity, beginning in 2009, will transport 1 million barrels (160 000 m³) of oil per day. It has a capacity of 10 million barrels (1.6 million m³) of oil, which will flow through the pipeline at 2 m (6 ft) per second. The pipeline will supply approximately 1% of global demand.

◆ Trans-Alaska Pipeline System

The Trans-Alaska Pipeline System is a major U.S. oil pipeline connecting oil fields in northern Alaska to a sea port where the oil can be shipped to the Lower 48 states for refining. The main Trans-Alaska Pipeline runs north to south, almost 800 miles (1,300 km), from the Arctic Ocean at Prudhoe Bay, Alaska to the Gulf of Alaska at Valdez, Alaska, passing near several Alaskan towns. Construction of the pipeline presented significant challenges due to the remoteness of the terrain and the harshness of the environment it had to pass through. Between Arctic Alaska and Valdez, there were three mountain ranges, active fault lines, miles of unstable, boggy ground underlain with frost, and migration paths of caribou and moose. Since its completion in 1977, the pipeline has transported over 15 billion barrels (2.4 km³) of oil.



◆ West-East Gas Pipeline Project

The West-East Gas Pipeline is a 4,000-kilometers long pipeline, which runs from Lunnan in Xinjiang to Shanghai. The pipeline passes through 66 counties in the 10 provinces in China. The construction of the West-East Gas Pipeline started in 2002 and it was put into operation on 1 October 2004. The pipeline is owned and operated by the Natural Gas and Pipeline Company, subsidiary of PetroChina. The gas will be used for electricity production in the Yangtze River Delta area.

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Student Worksheet: You are the Engineer!

◆ You are a team of engineers which has to tackle the challenge of developing a pipeline system to transport a golf ball and a ping pong ball from one side of your classroom to the other. But, it's not as simple as it sounds! You need to incorporate four angles in your design, one of which is a right angle (90 degrees) and the difference in height from one end of your pipe to the other can be no more than 18 inches. Your teacher may identify environmentally protected areas, water, or other hazards in your classroom that you'll have to consider in your plan.



◆ Planning Steps

1. Review the various Student Reference Sheets.
2. As a team, develop a plan for your pipeline. Draw it in the box below, and include other identifying features of your classroom such as doors, desks, or other areas:

◆ Construction Stage

1. Build and test your pipeline using both a golf ball and a ping pong ball.
2. Observe the pipelines constructed by other teams in your classroom

◆ Evaluation and Reflection

1. Complete the evaluation sheet and present the work of your team to the class.

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Student Worksheet: Evaluation/Reflection

Use this worksheet to evaluate the different pipelines developed by the "engineer" teams in your class.

1. What challenges did you face in executing your pipeline?
2. Did you find you needed to rework your original plan when you began building the real pipeline in the classroom? If so, how did your pipeline change?
3. Did you find your pipeline was more effective using the ping pong ball or the golf ball? Why do you think this was true?
4. Which pipeline developed by another "engineering" team did you think worked best? Why?
5. If your design were scaled up to a real pipeline, do you think you would need pumps to keep the materials flowing through your system? Why or why not? And, if so, how many pumps would you add, and where would you put them?
6. Do you think your pipeline design would work if you used it to transport water? Feathers? Butter? Why or why not?
7. Did you find that there were many ways to solve this challenge? If so, what does that tell you about the engineering designs of real pipelines?
8. Do you think you would have been able to create a successful pipeline as easily if you had not been working in a team? What are the advantages of teamwork vs. working alone?
9. How do you think engineers on the Baku-Tbilisi-Ceyhan Pipeline determined that they needed eight pumps to run the length of the project?
10. How do you think engineers working on the Alaskan Pipeline attempted to avoid negative environmental impact in Alaska? Did they succeed?

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For Teachers:

Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (<http://www.nextgenscience.org/>)
- International Technology Education Association's Standards for Technological Literacy (<http://www.iteea.org/TAA/PDFs/xstnd.pdf>)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (<http://www.nctm.org/standards/content.aspx?id=16909>)
- U.S. Common Core State Standards for Mathematics (<http://www.corestandards.org/Math>)
- Computer Science Teachers Association K-12 Computer Science Standards (<http://csta.acm.org/Curriculum/sub/K12Standards.html>)

◆ **National Science Education Standards Grades K-4 (ages 4 - 9)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ◆ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ◆ Abilities of technological design
- ◆ Understanding about science and technology
- ◆ Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ◆ Changes in environments
- ◆ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ Science as a human endeavor

◆ **National Science Education Standards Grades 5-8 (ages 10 - 14)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ◆ Motions and forces
- ◆ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ◆ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ◆ Populations, resources, and environments
- ◆ Risks and benefits
- ◆ Science and technology in society

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For Teachers:
Alignment to Curriculum Frameworks

◆ **National Science Education Standards Grades 5-8 (ages 10 - 14)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ History of science

◆ **National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ◆ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ◆ Abilities of technological design
- ◆ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ◆ Natural resources
- ◆ Environmental quality
- ◆ Natural and human-induced hazards
- ◆ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ◆ Historical perspectives

◆ **Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- ◆ 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- ◆ 3-5-ETS1-1. Define a simple design problem reflecting a need/want that includes specified criteria for success & constraints on materials, time, cost.
- ◆ 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- ◆ 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆ **Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Earth and Human Activity

Students who demonstrate understanding can:

- ◆ MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Pipeline Challenge



For Teachers:

Alignment to Curriculum Frameworks

◆ Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- ◆ MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆ Next Generation Science Standards Grades 9-12 (Ages 14-18)

Earth and Human Activity

- ◆ HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Ecosystems: Interactions, Energy, and Dynamics

Students who demonstrate understanding can:

- ◆ HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Engineering Design

Students who demonstrate understanding can:

- ◆ HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆ Standards for Technological Literacy - All Ages

The Nature of Technology

- ◆ Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- ◆ Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- ◆ Standard 5: Students will develop an understanding of the effects of technology on the environment.

Design

- ◆ Standard 9: Students will develop an understanding of engineering design.
- ◆ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- ◆ Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- ◆ Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.
- ◆ Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

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