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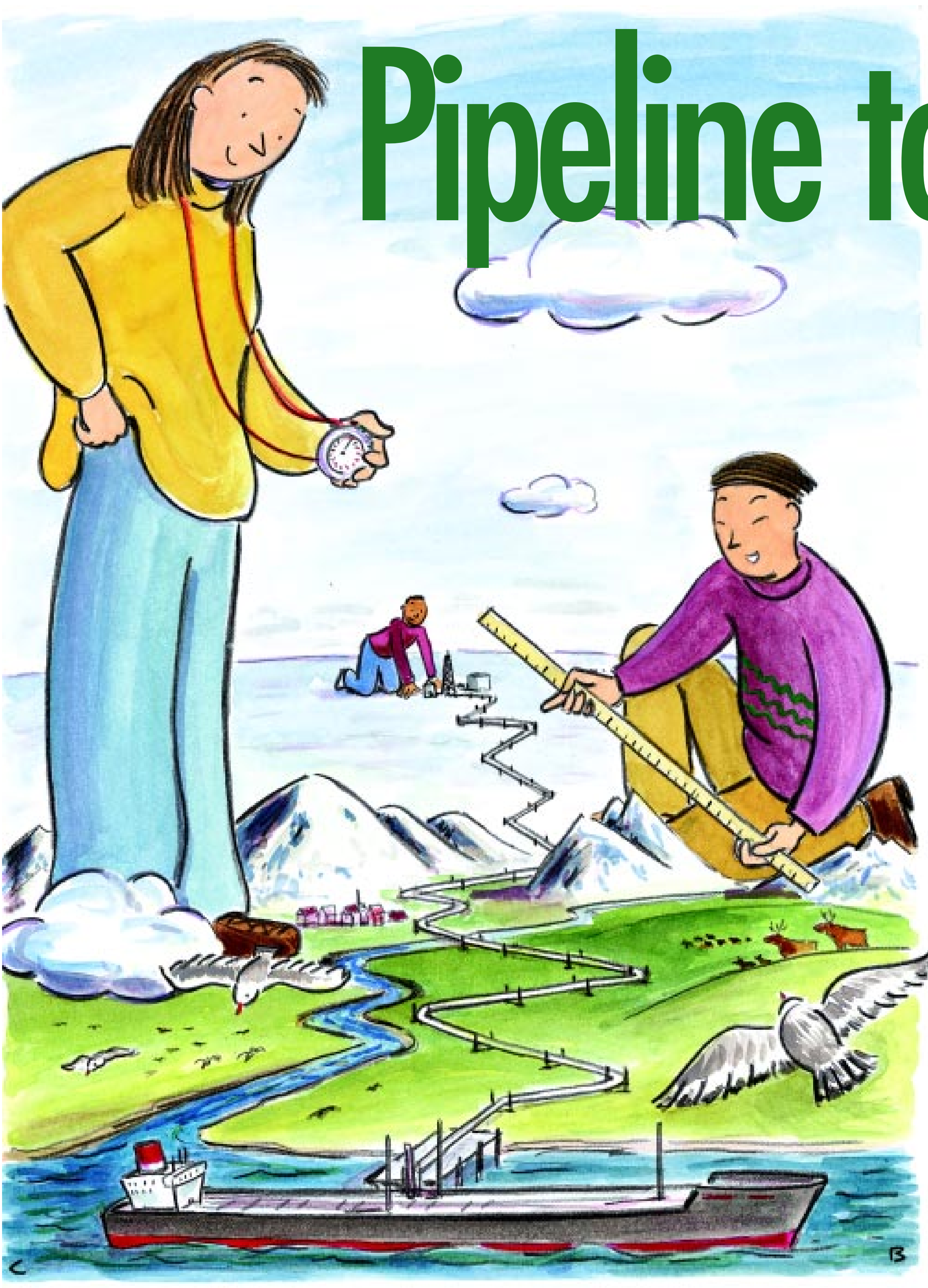

ART BY CHARLES BEYL

Environmental Awareness

In a simulated pipeline construction project, students apply physics, mathematics, and environmental biology

HARNESSING PETROLEUM ENERGY IS an excellent topic for interdisciplinary work because it necessitates research into exploration, production, transport, and conversion. Students can research such topics as biological and environmental effects of oil spills and can be challenged with mathematical problems related to gravity flow and pressure gradients in a pipeline and the relationship between pipe diameter and volume. Furthermore, because harnessing energy has economic and social implications, students can learn about the importance of economic efficiency in a world market.

Many of these topics seem abstract to middle and high school students, so we developed a concrete investigation that incorporates many of the topics mentioned above. We begin by explaining that modern society depends heavily on the energy produced by petroleum and that the petroleum industry is an important economic force, employing a large sector of the American public. We place students in the roles of engineers faced with the challenge of building a pipeline to transport oil across arctic tundra to tankers waiting at a seaside port. This investigation uses a guided-inquiry approach to teach about energy-related topics and may be used to introduce energy topics or as a culminating project that allows students to apply what they have learned.

ARCTIC PIPELINE

Designing and building a pipeline to transport petroleum from an inland arctic well to an oceanic tanker is a difficult challenge. Important considerations are the difficulty of crossing mountains, rivers, and permafrost; the need to minimize disturbance to human settlements and calving and nesting grounds of sensitive wildlife species; and the monetary costs of materials and construction. Engineers face these and other challenges as they decide how to wind a pipeline across such a complex landscape. Their design must minimize risk to the environment and cost to their company while enabling the quick and efficient transport of petroleum.

Petroleum transport is a complex endeavor that necessitates the consideration of many factors related to environmental and material costs as well as the physics of flow. For example, petroleum pipelines are susceptible to spills due to material and construction failure, seismic activity, flooding, and permafrost action. An oil spill can have serious environmental implications. Spilled oil can block sunlight and interfere with the gas exchange needed for photosynthesis, and its ingestion by animals may cause death through stomach and intestinal ulceration. Petroleum spills can be especially detrimental in aquatic

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systems, where areas far from the original spill site may be affected. Oil destroys the insulating and buoyancy properties of fur and feathers, can poison fish, and can do further damage to animals, including humans, when it is consumed indirectly as it passes through the food chain.

Pipeline construction may alter habitats through the direct removal of vegetation and by permafrost destabilization. Increased activity may disturb sensitive wildlife species, especially near breeding and rearing sites. Incidental activities, such as increased hunting, may also affect wildlife species (Montana Department of Natural Resources and Conservation, 1980). Pipeline construction near human habitations may be aesthetically undesirable or disruptive to traditional ways of life, but it may have substantial positive economic impacts. Potentially negative impacts may be mitigated by using better (and often more expensive) materials and construction methods (Bullion, 1995), and by engineering routes through less sensitive areas (MDNRC, 1980).

Petroleum engineers must also consider concepts such as pressure gradients within a pipeline, the nature of flow in the system (laminar versus turbulent), and the relationship between fluid viscosity and temperature. Poiseuille's law describes the volume flow rate (Q) of liquids flowing through tubes:

$$Q = \frac{\Delta P \pi r^4}{8 \mu l}$$

Where (ΔP) = change in pressure
(r) = radius of pipe
(μ) = viscosity of fluid
(l) = length of pipe.

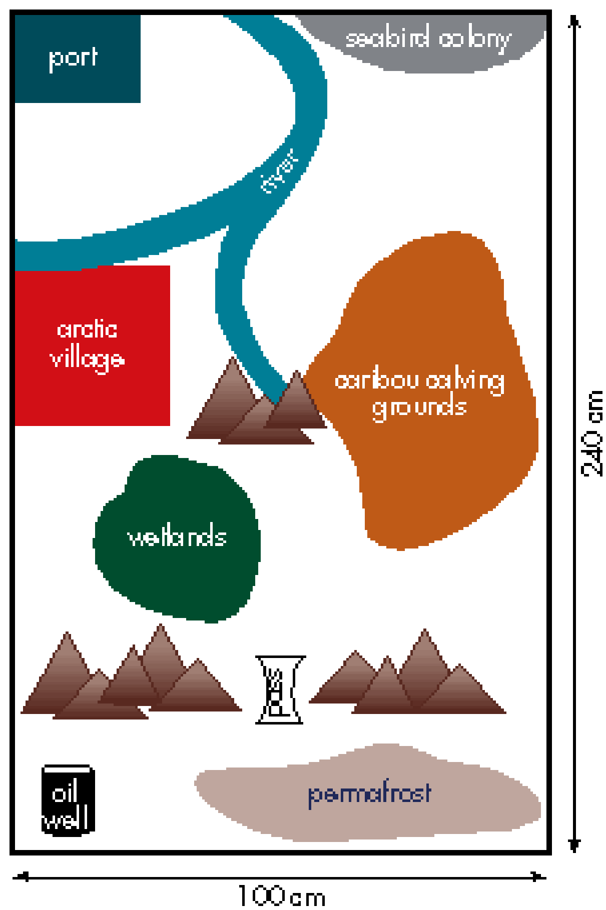
STUDENTS AS ENGINEERS

During this investigation students work in groups of three to five to build a pipeline using CPVC pipe to transport "petroleum" across a miniature landscape from an oil well to a seaside oil tanker. Students must consider the speed of delivery, cost of materials, and potential hazards to humans and the environment. At the end of the investigation, the pipeline design is evaluated against a point system in which groups attempt to minimize the number of points accumulated during construction.

Prior to the investigation, each group of students was provided with a description of the point system, a data sheet, and materials to simulate a miniature landscape, an oil well, an oil tanker, and oil. We constructed each landscape using three 80- × 100-centimeter sheets of foamboard which were taped together to form a 100- × 240-centimer working space. The mountain ranges were made from posterboard taped onto predetermined sites, and features such as locations of the oil well and tanker (at opposite ends of the landscape), a seabird nesting colony, caribou calving grounds, wetlands, a town, and a river were painted on the surface (Figure 1). It is important that every landscape used in a single class be identical so that no group is given an unfair advantage and so students can compare their results with those of other groups.

We simulated the oil wells by drilling a 1-inch hole (approximately 25 millimeters—as metric drill bits are difficult to find in the United States, it is best to use a 1-inch drill bit for this part of the exercise so that the hole will fit the pipe material) in a 20-liter plastic bucket, putting a rubber gasket around the hole, and fitting a piece of 3/4" CPVC pipe (approximately 19 millimeters—most U.S. readers will have to buy the 3/4" size pipe) through the opening. The protruding end of the pipe was inserted into a CPVC valve with a handle, and silicone sealant was applied around the joint. To facilitate filling and ensure adequate head pressure, a fill line was drawn at the 4-liter level.

FIGURE 1.
Simulated landscape.



Students must consider the speed of delivery, cost of materials, and potential hazards to humans and the environment.

Pancake syrup diluted with water (two parts syrup to one part water) was used to simulate oil because it is safe and viscous enough to flow easily through the pipes. A plastic milk container with the top cut off was used as the oil tanker. A fill line was drawn on the tanker at the 1-liter level so that students did not overfill the container.

We provided varying lengths of both 1/2" and 3/4" CPVC pipe (Figure 2) to simulate the influence of pipe diameter on the delivery of oil. The pipe was precut into lengths and made available to the class in a central location. We also gave each team sponges, a funnel for transferring syrup, duct tape to seal leaky joints, a tape measure, a calculator, and a stopwatch. A hot plate and pot for heating the syrup were also available for students wishing to explore the relationship between flow and temperature.

Teachers and students can explore the scientific and decision-making processes used in constructing pipelines.

To begin the investigation, teams were given landscapes with oil wells in place. (We suggest filling the wells before the activity begins or while students are designing their pipelines.) The objectives of the investigation, the point system to calculate the cost of the pipeline (Figure 3), a data sheet, and precautionary information necessary to prevent major syrup spills were explained to students.

Engineering teams built the pipeline they thought would cost the fewest points. When all joints had been checked for tightness, the spigot was opened, and the stopwatch was started. The finish time, when the fill line was reached on the tanker container, was recorded on the data sheet. The length and diameter(s) of the pipeline, number of fittings, landscape features crossed, and any spills were also recorded. Students were given time to calculate pipeline costs.

Groups were expected to construct their pipeline and complete at least one run of petroleum transport within 45 minutes. Their times varied, depending largely on how much time they spent planning their design rather than simply jumping into the building phase. Clean-up time was about 15 to 20 minutes.

FIGURE 2.

Pipe supplies needed for each group of students. (Note: English units have been used in this case because the majority of readers live in the United States where they must buy equipment from hardware stores that only carry supplies in English units.)

Pipe length/fitting	Number of 1/2" pieces	Number of 3/4" pieces
1.5"	3	4
3"	3	4
6"	3	4
12"	3	4
18"	2	3
couple	3	4
45° elbow	2	2
90° elbow	3	3
1/2"–3/4" bushing	2	2

FOLLOW-UP AND ASSESSMENT

In follow-up discussions, teachers and students can explore the scientific and decision-making processes used in constructing pipelines. As each engineering team describes their pipeline to the class, there are many opportunities to assess understanding. For example, why did they choose to construct their system in a certain way? Which designs seem to work best? What are the relationships between pipe length, pipe diameter, number of bends in the pipe, vertical rise of the pipe, oil temperature, and the rate of flow?

Questioning students on how and why they made their choices can lead to discussions about decision-making and how science contributes to that process. More advanced students might be asked to discuss how engineering concepts such as pressure gradient, laminar versus turbulent flow, and the relationship between viscosity and temperature influenced the design and

FIGURE 3.

Petroleum transport sample point list. (Note: English units have been used in this case because the majority of readers live in the United States where they must buy equipment from hardware stores that only carry supplies in English units.)

Item	Points
1/2" pipe	1 per inch
3/4" pipe	2 per inch
1/2" fittings	2
3/4" fittings	4
Permafrost wetland	35
Caribou calving area	25
Arctic village	25
Seabird colony	25
Over river	35
Through river	50
Spills	50 each
Heating	25 per minute
Time	1 per second

performance of their pipeline. As a follow-up, students can be asked to use the Poiseuille law to redesign their pipeline. Lively discussions may also evolve from considering costs assigned for containing environmental damage. The point system is flexible, and outcomes will depend on the relative weight given to each component. The factors engineers must consider as they weigh project costs and benefits can be discussed in the context of market values of commodities and how those values are decided and enforced by society.

If the activity is used early in a unit on energy, students might be asked to write an essay on why they designed their pipeline the way they did, what factors they considered, and how their design affected results. They could also be asked to explain how changing a factor like pipe diameter or length would affect flow rate, and how this could be tested. If used as a culminating project, the inquiry itself could serve as an excellent assessment tool. Students would pull together diverse sets of information to make decisions and hone and demonstrate their skills in integrating and applying knowledge to new, realistic situations.

This activity can be easily adapted to individual teaching styles and classrooms.

ADAPTING THE LESSON

This activity can be easily adapted to individual teaching styles and classrooms. Some teachers could even design a landscape that mirrors their geographical area, especially if petroleum transport occurs locally. Students could be given the opportunity to redesign their system based on knowledge they gain after the first run if new information is introduced or if they are able to do more research about the subjects. Students could then compare how additional learning affected their design process and the outcome of the pipeline.

This activity can serve as a model for future projects related to other subject areas. Integration of scientific information and processes with social and personal values can be carried out in an almost endless number of settings. The processes students use to design their pipelines can be applied to such diverse situations as planning for urban development; licensing a mine, oil well, or hydroelectric dam; planning a timber sale; or designing a recreation plan for a public-use area. ✧

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