AN INTRODUCTION TO THE
NATURE OF SCIENCE AND TECHNOLOGY

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**Focus:**

These activities introduce the nature of science and technology. The teacher uses a numbered cube to involve the students in asking a scientific question and proposing a scientific explanation. The teacher then presents the students with a problem using the same cube. The students propose solutions to the problem. The teacher uses these activities to introduce the nature of science and technology. The teacher presents the students with another cube and asks them to propose an explanation. Finally, there is a cube that the teacher can use for an evaluation.

The unit emphasizes themes one and two—*science is a way of explaining the world* and *technology is a way of adapting to the world*. The activities address the following questions:

- What is science?
- What is technology?
- What are the relationships between science and technology?
- What are some of the processes of science and technology?

**Learning Outcomes:**

This unit will help students develop a better understanding of the nature of science and technology. Specifically, the activities and explanations should provide students with initial definitions of science and technology and help them differentiate scientific questions from technological problems. The activities also introduce concepts and skills such as data, inference, hypothesis, and observation. The students will also learn how to use data to strengthen their argument and the importance of communicating results as part of the process of science.

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This activity is based on an original activity entitled “The Three Cube Method of Introducing Inquiry” developed by Joe P. Buckingham. The modified activities are used with permission.
**Background Information:**

Science teachers primarily teach the facts, information, concepts, principles, and theories of science, and to a much lesser degree of technology. This activity is about science and technology. What is it about science and technology that is important for students to know and value? This activity helps students answer questions they frequently ask--What is science? What is technology? This activity also serves to illuminate the relationships between science and technology, a relationship that is becoming increasingly important in society.

We distinguish science and technology as follows:

**Science** proposes explanations for observations about the natural world.

**Technology** proposes solutions for problems of human adaptation to the environment.

Figure 1 is a schematic showing the interrelationships between science and technology. An explanation of the connections and the distinctions between science and technology as presented in figure 1 follows.

Science begins with questions about the world. How do earthquakes occur? What causes the different seasons in the northern and southern hemispheres? Why do some children look like their parents? While we have simplified these questions for clarity (scientists ask more specific questions), the nature of the questions asked by students and scientists is the same; that is, the questions are about phenomena occurring in the natural world. As scientists proceed to answer these questions, they employ recognized, though variable, methods of rational inquiry. There are "rules of the game" that scientists use. For example, scientists base their explanations on, or derive them from, observations. Historically, those observations were direct; now, scientists often use technology to make observations.

In figure 1, the word *propose* suggests that scientific explanations are tentative, a basic idea in science. Scientific explanations are subject to change and do not purport to be the final truth. The word *propose* also suggests that scientists make their explanations known to others. That is, scientists make their explanations public through such means as presentations at professional meetings and publication in refereed journals.

The pursuit of science begins with questions about the natural world; technology starts with problems of human adaptation (see figure 1). Humans need air, water, food, and safety. They need to move objects and information, they need to construct shelters and bridge rivers. These, and other historical examples of technology, such as the development and use of tools, agriculture, weapons, and compasses, illustrate the origin of technologies as issues of human
The Relationship Between Science and Technology and their Connection to Educational Goals

Science
(Originates in questions about the natural world)

Applies Methods of Inquiry

Proposes Explanations (for phenomena in the natural world)

New Questions

Social Applications of Explanations and Solutions

Personal Actions Based on Explanations and Solutions

Technology
(Originates in problems of human adaptation in the environment)

Applies Problem-Solving Strategies

Proposes Solutions (to human problems of adaptation)

New Problems

Figure 1
adaptation. Technology extends the human ability to change the world but the changes originate in a need for humans to adapt to the world. We recognize that some technology is an expression of human aspirations, for example, art. This, too, can be thought of as adaptation, though not on a survival level.

There are many possible solutions to problems of human adaptation, and inevitably there are objectives and requirements to consider. Some of these are constraints, such as availability of materials, properties of materials, scientific laws, and cultural requirements. Other variables in contemporary society include cost, benefit, risk, and environmental impact. Engineers often complete several designs for a single project so they can assess trade-offs among constraints and variables before deciding about the best solution. While the methods of scientific inquiry and technological problem solving have many common elements, we distinguish the latter by a focus on such issues as constraints, control, materials, cost-risk-benefit analysis, and decision making. Examples of concepts and skills include decision-making techniques, modeling and simulation techniques, information and communication, systems analysis, and technology assessment.

The distinctions between science and technology are relatively subtle. Simple definitions such as "technology is applied science" no longer sufficiently explain the relationship between science and technology. As the center arrows in figure 1 indicate, there are interactions between the methods of inquiry and problem-solving strategies and between scientific explanations and technological solutions. Technology depends on accurate scientific information and cannot contravene scientific laws. Science depends on technology to provide instruments and capabilities that enable collection of new or more refined observations (data).

Students should begin to understand the following differences between science and technology.

1. Science is an attempt to construct rational explanations of the natural world. Technology is an attempt to provide rational solutions to human problems.

2. Scientific explanations about the natural world are always tentative; they continue to evolve. Technological solutions are always incomplete and imperfect.

3. Technologies exist within the context of nature; that is, no technology can contravene biological and physical principles.

4. All technologies have side effects.

5. All technologies carry some risk because they are incomplete and imperfect. Correspondingly, the degree to which any society depends on technology is also the degree to which the society must bear the burden of risk.
Scientific and technological enterprises result in socially helpful products. The direct outcome of science is a better understanding of the world and generalizable explanations. Technological solutions are more specific and tangible, taking the form of products or services. In either case, however, individuals and society make decisions and take actions in response to the outcomes of science and technology (see figure 1). These actions and decisions move science and technology directly into the realm of personal uses and public policy.

The influence of science and technology on society is clear in such developments as a theory of relativity, a model for DNA, explanations for weather, gunpowder, the compass, and the cotton gin. More subtle are relationships between science and technology and the social power structure. Scientific questions and technological problems chosen for research and development actually support the prevailing power structure, because that structure has the money and influence to induce change.

Earlier, we mentioned physical and social changes of science and technology. There have also been changes in our perceptions about the natural and designed world. The shift from a geocentric to a heliocentric world view is an example of such a change. In more recent times, as science illuminated our understanding of such processes as photosynthesis and the hydrologic cycle, humans of necessity changed their perceptions about the interrelatedness of life on Earth and about the effects of industrial pollution and deforestation.

We have listed some of the characteristics of science and technology that are important for students to understand.

1. The distinctions between science and technology.
2. Scientists and technologists use the same data for different positions on the same issue.
3. Society influences scientific research and technological development.
4. Science requires freedom of information, ideas, and discussion.
5. Science and technology have limits in their capacities to develop explanations and solutions.
6. Scientists and technologists are human.
7. Science and technology are social resources.
8. Science and technology are unique ways of knowing and adapting; there are other ways of knowing and adapting.
Returning to figure 1, we see that scientific and technological outcomes themselves raise new questions and problems. The processes represented in figure 1 are, therefore, interactive. The interactions can develop new explanations and solutions or amend those already developed. These interactions show the open-ended nature of science and technology.

Historically, humans have developed different ways of knowing about the world and solving problems of adaptation. Important examples for this discussion are science and technology. Both science and technology have distinct origins, "rules," and results. Development of scientific and technological literacy at the middle level should include an understanding about science and technology and their place in society.

**Materials and Equipment:**

- Cubes (black-line masters are provided.)
- 10 small probes such as tongue depressors, pencils.
- 10 small pocket mirrors.

**Instructional Activities:**

**Engagement** (Ten minutes of the first class period.)

Begin by asking the class to tell you what they know about science. How would they define science? Technology? The point of this introduction is to get students thinking about science and technology. It is also an opportunity for you to assess their current understanding of science and technology. Try to accept their answers and record key ideas on the overhead or chalkboard.

**Exploration** (The remainder of the first class period.)

(Note: The first cube activity can be done as a demonstration if you construct a large cube and place it in the center of the room.) First, have the students form groups of four. Place the cubes in the center of the table or bench where the students are working. The students should not turn, lift, or open the cube. Tell the students there is a question, but they have to identify the question. Allow the students to state their questions. Likely questions include

- What is in the cube?
- What is on the bottom of the cube?
- What number is on the bottom?
Your task is to direct students to the general question about what is on the bottom of the cube. You should point out there is not enough data to conclude what is on the bottom.

Tell the students that they will have to answer the question--what is on the bottom?--by proposing an explanation; and, that they will have to convince you and the other students based on evidence. (The latter refers to observations the group can make about the sides of the cube.) Allow the students time to explore the cube and answers to the question. Some statements of fact that the students may develop are

- the cube has six sides.
- the cube has five exposed sides.
- the numbers and dots are black.
- the exposed sides have numbers 1, 3, 4, 5, and 6.
- the opposite sides add up to seven.
- the even-numbered sides have dots.
- the odd-numbered sides are plain.

Ask the students to use their observations (the data) to propose an answer to the question -- What is on the bottom of the cube? The student groups should be able to make a statement such as--We conclude there is a 2 on the bottom. Students should base this conclusion on the observation that the exposed sides are 1, 3, 4, 5, and 6. Since 2 is missing from the sequence, we conclude it is on the bottom.

Use this opportunity to have the students develop the idea that combining two observations creates a strong proposition. For example, 2 is missing in the sequence (that is, 1, _, 3, 4, 5, 6) and that opposite sides add up to 7 (that is, 1-6, 3-4, _,-5) and since 5 is on the top and 5 and 2 equal 7, 2 must be on the bottom.

Now, using the same cube, introduce the students to a technological problem. Tell the students--Suppose you wanted to carry materials in the cube. Would it work? The vague question may puzzle the students. They may ask--What materials?--How will you get material into the cube?--How much material? Now tell the students, suppose you wanted to carry popcorn in the cube. Would it work? (You would have to devise a way to open he cube and a way to carry conveniently the cube.) Suppose you wanted to carry lead shot in the cube. (The cube would not be strong enough. You would need a different material, perhaps cardboard or wood.)
Ask the students to use their observations and experiences to propose an answer to the problem of carrying popcorn (popped) in the cube. They should account for requirements, such as keeping it warm, transporting it, and not getting stains on clothes from the butter.

You have subtly introduced the students to differences between science and technology. In the second use of the cube, they had to solve a technological problem, not answer a scientific question. They also had requirements and specifications to consider in solving the problem.

Put the cube away without showing the bottom or allowing the students to dismantle it to solve the popcorn problem. If seeing the bottom concerns the students, explain that scientists are also certain about their proposed answers, and often have no way of knowing they are absolutely correct.

**Explain** (Second class period.)

Begin the class period with an explanation of how the activity simulates scientific inquiry and technological problem solving. Refer to background information and use the diagram (figure 1 in background) on the overhead. Key points include the following:

- Science originates in questions about the world.
- You used observations to construct a proposed explanation (answer to the question).
- The more observations you had that supported your hypothesis, the stronger your answer.
- Scientists propose explanations.
- Technology originates in human problems.
- Engineers must consider requirements in solving technological problems.
- Engineers propose solutions.

Please note we have said nothing about "The Scientific Method." The students had to struggle to answer the question and probably did it in a less than systematic way. Identifiable elements of a method such as observation, data, and hypothesis were clear but not applied systematically. You can use the experiences to point out and clarify observation, hypothesis, and use data to formulate a logical explanation.

**Elaboration** (Third class period.)

The main purpose of cube #2 is to extend the concepts and skills introduced in the earlier activities and to introduce the role of prediction, experiment, and the use of technology in
scientific inquiry. The problem is the same as the first cube--What is on the bottom of the cube? Divide the class into groups of three and instruct them to make observations and propose an answer about the bottom of the cube. Student groups should record their factual statements about cube #2. Let the students struggle some with the details. If the students are becoming too frustrated, provide help with guiding questions.

Essential data from the cube include the following:

- Names and numbers are in black.
- Exposed sides have either a male or female name.
- Opposing sides have a male name on one side and a female name on the other.
- Names on opposite sides begin with the same letters.
- The numbers in the upper right corner of each side corresponds with the number of letters in the name on that side.
- The number in the lower left corner of each side corresponds to the number of the first letter the names on opposite sides have in common.
- The number of letters in the names on the five exposed sides progresses from 3 (Rob) through 7 (Roberta).

Four names, all female, could be on the bottom of the cube: Fran, Frances, Francene, and Francine. There is not data to show the exact name, so groups may have different hypotheses. Tell the student groups that scientists use patterns in data to make predictions and then design an experiment to assess the accuracy of their prediction. This process also produces new data.

Tell the groups to use their observations (data) to make a prediction of the number in the upper right corner of the bottom. The predictions will most likely be 4, 7, or 8. Have the team decide which corner of the bottom they wish to inspect and why they wish to inspect it. The students may find it difficult to determine which corner they should inspect. Let them struggle with this and even make a mistake—that is part of science! Have one student obtain a utensil such as tweezers, probe, or tongue depressor, and a mirror. The student may lift the designated corner two centimeters (less than one inch) and try to look under the cube. The groups should describe the data they gained by the experiment. Very importantly, they should describe the problem they solved in order to answer the question, and the role of technology in this experiment.

If students observe the correct corner, the students will discover an 8 on the bottom. This observation will confirm or refute the students' working hypothesis. There are two possible names on the bottom, Francene and Francine. The students propose their answer to the question
and design another experiment to answer the question. Put the cube away without revealing the bottom. Have the students present brief reports on their investigation.

**Evaluate** (Fourth class period.)

The final cube is an evaluation. In groups of three, the students should address the same question—What is on the bottom of the cube? They should follow the same rules, for example, they cannot pick up the cube. The groups should prepare a written report on the final cube. (You may have the students present oral reports using the same format.) The report should include the following:

- title page,
- question,
- observation-data,
- experiment-new data,
- proposed answer and supporting data,
- a diagram of the bottom of the cube, and
- suggested experiments.

Due to the multiple sources of data on each side, this cube is quite difficult for students. It may take more than one class period and you may have to help with some information, such as London Bridges or Eiffel Towers, that students may lack.

- Some pertinent information for this activity are
- white background with black letters and numbers are the exposed sides.
- two sides do not have compartments.
- two sides have compartments.
- one side has four compartments.
- there is a relationship between the sides with the same number of compartments.
- numbers in the upper left corner of each side are the same as the number of compartments on that side.
- letters in the upper right corner are the same on opposite sides.
- numbers on the lower left corner of exposed sides are in sequence 1, 2, 3, 4, _, 6.
- numbers in the lower right corner of the cube are 1, 2, 4, 7, 11, _.
• corresponding sides have complements to the statements from opposite sides.

• Each side has an indication for the missing letters, words, or symbols. Examples are T _ L _ _ R _ P H, MORSE _ _ _ _, and •••, ---, __.

Remember that this is an evaluation. You may give some helpful hints, especially for information, but not for concepts or procedures.

Student groups should complete and hand in their reports. You may wish to have groups present oral reports (have a scientific conference). This is one activity for which you may wish to show the bottom of the cube.

**Going Further:**

• Students can review an actual scientific paper to determine the parallels to their reports.

• Review a book on scientific discovery such as *The Double Helix*.

• Students can set up a project in which they actually investigate a scientific question.

• Provide students with the "requirements specifications" for a simple technological problem (examples include an egg drop, a toy for a young child, and an ice cream container) and let them solve the problem.
CUBE #1

White background
Black dots
Black numbers

→ bottom
CUBE #2

Black names and numbers
Opposite sides are the same color
White:
ALMA&ALFRED
Blue border:
ROB&ROBERTA
Red border:
FRANK&FRANCENE

→ bottom
CUBE #3

Tower

London

B

2

AM A
YS

A

E:

EG A

S

MORSE

4

3

BRIDGE

EIFFEL

4

7

S

C

CODE

TLRPH

5

16

→ bottom
CUBE #4

\[ F(x) = \frac{x^2 + x}{x} \]
CUBE #5

No patterns

→ bottom
CUBE #6

#'s correspond to letters of the alphabet

#'s on cube represent 1st 6 vowels

→ bottom
CUBE #7

1st letters vary as consecutive letters of the alphabet that form words with __ A T

→ bottom