Temperature Tactics

Lesson Focus

Lesson focuses on how thermometers have been impacted by engineering over time, and also how materials engineering has developed temperature sensitive materials. Student teams design and build a temperature gauge out of everyday products and test a variety of materials for thermal properties. Students evaluate the effectiveness of their temperature gauge and those of other teams, and present their findings to the class.

Lesson Synopsis

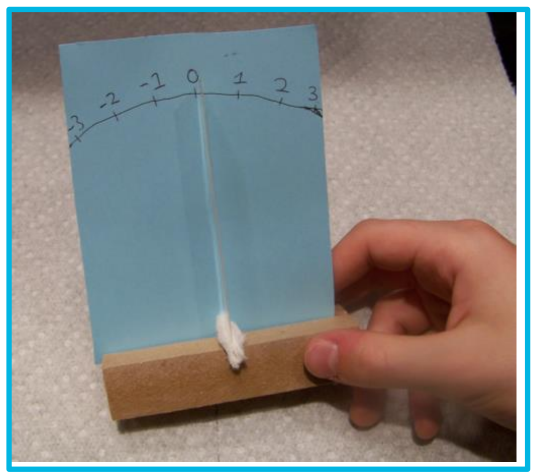
The "Temperature Tactics" activity explores the devices used over time to measure changes in temperature. Students work in teams of "engineers" to design and build their own temperature gauge out of everyday items. They explore how various materials change when temperatures decrease, evaluate their results, and present reflections to the class.

Age Levels

8-14.

Objectives

- Learn about sensors that measure temperature.
- Learn about engineering design.
- Learn about properties of materials.
- Learn about teamwork and problem solving.



Anticipated Learner Outcomes

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

- material properties
- sensors and thermometers
- engineering design
- teamwork

Lesson Activities

Students explore the impact of engineers and scientists have developed sensors over the centuries to measure temperature. Students explore a range of temperature sensitive materials, and work in teams to develop a temperature gauge out of everyday items. They test their gauge in a freezer or refrigerator, evaluate their own designs and those of other students, and present their findings to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- NASA Global Temperature (https://climate.nasa.gov/vital-signs/global-temperature/)

Recommended Reading

- A History of the Thermometer and Its Use in Meteorology (ISBN: 0801871530)
- Inventing Temperature: Measurement and Scientific Progress (ISBN: 0195171276)

Optional Writing Activity

- Write an essay or paragraph about why a farmer might need to use a sensor to gauge the temperature of soil.

For Teachers:
Teacher Resource

◆ Lesson Goal

Lesson focuses on how thermometers have been impacted by engineering over time, and also how materials engineering has developed temperature sensitive materials. Student teams design and build a temperature gauge out of everyday products and test a variety of materials for thermal properties. Students evaluate the effectiveness of their temperature gauge and those of other teams, and present their findings to the class.

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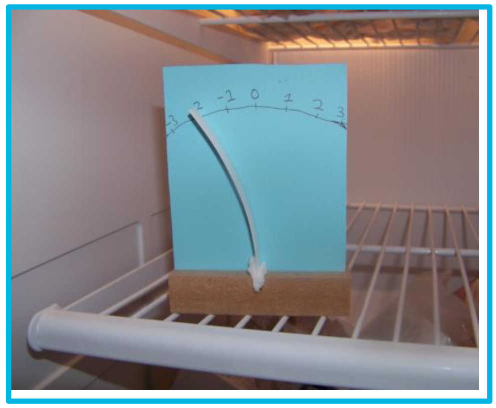


◆ Materials

- Student Resource Sheets
- Student Worksheets
- Thermometer (used as reference to actual temperature), access to freezer, refrigerator, or cooler filled with ice
- One set of materials for each group of students:
  - Wooden stick, plastic tape, cardboard, pen, pencil, ruler, foil, paper

◆ 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 students must develop their own working device to measure decreases in temperature from the materials provided. Suggest that they might want to test the materials in combination to see if any of them change when they become colder.
4. Students meet and develop a plan for their temperature gauge. They agree on materials they will need, how their scale will work, write or draw their plan, and then present their plan to the class. The scale can be in numbers, letters, or symbols.
5. Student groups next build their temperature gauge. They may need to rethink their plan, request other materials, trade with other teams, or start over.
6. Student temperature gauges then are moved to a freezer (ideally) or a cooler filled with ice for at least an hour (this could be overnight as well).
7. Next….teams examine their temperature gauges and note how their sensor worked. (Be sure to have a real freezer thermometer available to show the actual temperature of the freezer or cooler.)
8. Teams then complete an evaluation worksheet, and present findings to the class.

◆ Time Needed

One to two 45 minute sessions.

◆ Tip:

A simple solution is to cut cardboard to a length of about 4 inches long and ½ inch wide, then cover one side with plastic tape. The tape will shrink on the "shiny" side when frozen forcing the cardboard to bend to a point.

Student Resource:
What is a Thermometer?

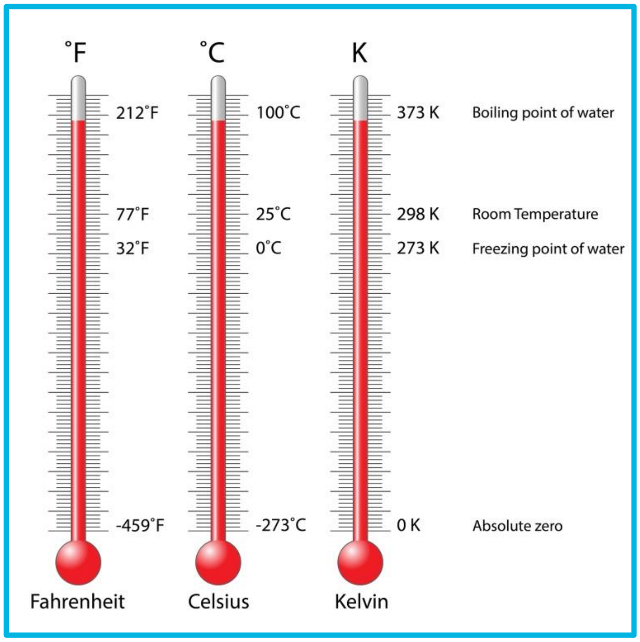
A thermometer is a sensor that measures the temperature of things. Thermometers can be used to gauge the temperature of your body, or the temperature of the air outside your home, or the air temperature inside an oven, or the temperature of food cooking in an oven. Depending upon the intended application, there are many different designs of thermometers that have been developed by engineers to meet different challenges.

◆ Early History

One of the earliest inventors of a thermometer was probably Galileo. Galileo discovered that glass spheres filled with aqueous alcohol of slightly different densities would rise and fall depending on the surrounding air temperature. You can see a sample of this type of thermometer on the right, and these are still available in stores as a decorative way to display temperature in a home.

◆ Temperature Scales

Thermometers usually measure temperatures in one of three scales: Fahrenheit, Celsius, or Kelvin. Fahrenheit is used mostly in the United States, while most of the rest of the world uses Celsius. German physicist Gabriel Fahrenheit developed the scale that bears his name 1724. In the Fahrenheit system, ice freezes at 32 degrees while water boils at 212 degrees. Fahrenheit decided that the range between the freezing point and boiling point of water should be 180 degrees.



Anders Celsius developed his scale in 1742. The "Celsius scale" was previously referred to as the "centigrade" scale -- meaning "divided into 100 degrees." Celsius decided that the freezing point of water should be 0 degrees and the boiling point should be 100 degrees. This scale is preferred by many because it is easily divisible by 10 and is similar to the structure of the metric measurement system.

Lord Kelvin of Scotland developed the "Kelvin scale" 1848. The Kelvin Scale is the standard that scientists and engineers use and is based on the theory that there is no upper limit on how hot a temperature can be, but that there is a limit on the cold end of the scale. Kelvin developed the idea of Absolute Zero, or 0 on the Kelvin scale, which converts to -273.15 degrees Celsius or -523.67 Fahrenheit. Absolute Zero is considered the lowest possible temperature. Great efforts have been made by scientists and engineers over the year to bring a material close to absolute zero -- no one has done it yet!

Student Resource:
How a Thermometer Works

You may be most familiar with a "bulb" thermometer which is used to gauge outdoor temperatures. You may see a red or silver line that moves up or down through a glass or plastic tube as the temperature changes. It moves up as it gets hotter and moves down the tube as temperatures cool. The liquid used to be a metallic liquid called mercury, but mercury has been found to have bad impacts on the environment, so more likely the liquid is a colored alcohol. A set of numbers are printed on the cardboard or plastic behind the tube to indicate the air temperature. The process of making sure the numbers relate properly to the actual temperature is called calibration.

Another common type of thermometer is a "spring" thermometer which includes a coiled piece of metal that is sensitive to temperature. One end of the spring is attached to a pointer, and as air heats, for example, the metal expands and the pointer moves higher. If the air cools, the metal contracts and the pointer moves lower. These types of thermometers are less accurate than a bulb thermometer, but are useful in non-critical situations such as determining whether you need to wear a coat to school or not!

◆ Current Innovations in Measuring Temperature

There are many new innovations in the development of sensors to measure temperature. These include electronic devices that gauge temperature from a person's ear or temple. These are less invasive and provide quicker and potentially more accurate readings than conventional oral thermometers.

◆ Temperature Sensitive Materials Solve Problems

Some materials change shape or color when cooled or heated. A strip of plastic tape will shrink a bit when frozen, for example. And, you may have heard of or seen "mood rings" - they change color when heated or cooled by your finger. The stone in a mood ring is actually a piece of hollow quartz or glass filled with thermochromic liquid crystals. Thermochromism is the ability of a material to change color due to a change in temperature. The crystals twist as their temperature changes (heated or cooled by your skin). The twisting changes their molecular structure, and adjusts how light is absorbed or reflected by them. When the temperature changes, so does the apparent color! Engineers took this concept and developed new application to help solve problems in society! Adhesive thermometers using temperature sensitive papers are now widely used on packages shipping medical supplies, foods that must stay within a range for safety, and in shipping blood and organs. And, you may have seen mugs that change color or show a picture when heated or filled with hot liquid.

Student Resource: Thermometer Reliability

As with many other sensors thermometers must be perform their tasks reliably and meet the needs of specific tasks. There are four factors to consider:

◆ Accuracy

Thermometers must be accurate in order to be reliable. They are usually "calibrated" either by comparing them with other certified thermometers or by checking them against known fixed points on the temperature scale, such as the boiling point of water.

◆ Sensitivity

For some applications a thermometer must be more sensitive, or provide more specific data than for others. For example, if you are considering whether to wear a sweater when heading outdoors, you may not need to know a specific temperature, but rather just know that the air is below a level at which you might feel cool. However, some thermometers must provide very specific data and so are more sensitive than others such as thermometers used in laboratories or medical manufacturing facilities.

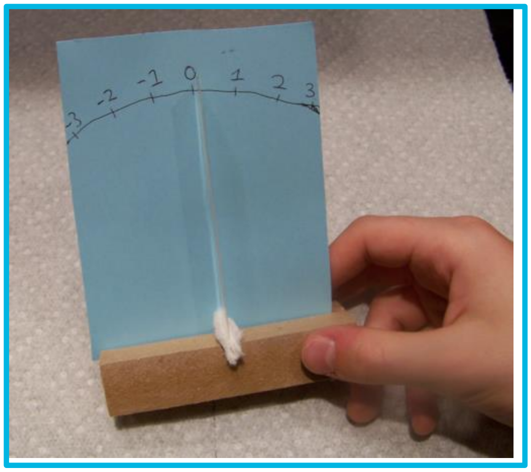
◆ Repeatability

A thermometer must be able to repeat its readings with consistency. Thermometers are usually developed to last a long time and provide continued, consistent readings.

◆ Scale/Range

The scale or range of the thermometer must meet the needs of the application. For example, the range of a meat or cooking thermometer must be able to determine higher temperatures than an oral human thermometer. A candy thermometer is similar to a meat thermometer except that it can read higher temperatures (usually 400°F/200°C or more). Or a thermometer designed to measure extremely cold temperatures (perhaps of ice or super cold liquids) would likely have a different scale or range than a typical outdoor thermometer.

Student Worksheet:
Design Your Own Temperature Gauge



You are working as a team of engineers who have been given the challenge to design your own working device to measure decreases in temperature from the materials provided by your teacher. You'll need to develop a scale that will show a range of temperatures including room temperature, a freezer, and perhaps other environments your teacher will select. Your thermometer must have a scale or range that meets your application, and be repeatable.

◆ Planning Stage
Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your thermometer. You'll need to determine what materials you want to use and how you'll attach them to a scale. Your scale is up to you -- it may contain positive and negative numbers, or letters or symbols!

Hint: You might want to do some advance testing by putting individual materials -- or materials you glue or attach together -- in a freezer to see in advance how they change with decreased temperatures.

Draw your design in the box below and present your design to the class. You may choose to revise your teams' plan after you receive feedback from class.

Materials Needed:

Student Worksheet (continued):

◆ Construction Phase

Build your temperature gauge. During construction you may decide you need additional materials or that your design needs to change. This is ok -- just make a new sketch and revise your materials list.

◆ Testing Phase

Each team will test their temperature gauge by leaving it in either a freezer or cooler filled with ice for at least an hour. Your teacher may have you leave your gauge in a freezer overnight. Be sure to watch the tests of the other teams and observe how their different designs worked.

◆ Observation

In the box below, indicate what "temperature" on your scale you observed with your device:

	Room Temperature	Freezer	Refrigerator	Other
Actual Thermometer Temperature				
1st Reading From Your Team's Temperature Gauge				
2nd Reading From Your Team's Temperature Gauge				
3rd Reading From Your Team's Temperature Gauge				

◆ Evaluation Phase

Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Student Evaluation Worksheet

Use this worksheet to evaluate your team's results in the "Temperature Tactics" lesson:

1. Did you succeed in creating a temperature gauge that changed to indicate a colder temperature? If not, why did it fail?

2. Was your temperature gauge able to repeat the tests with similar readings?

3. Did you decide to revise your original design or request additional materials while in the construction phase? Why?

4. Do you think your temperature gauge would also be able to measure heat? Why or who not?

5. List three applications where being able to accurately measure temperatures is critical to humans:

    1.
    2.
    3.

6. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

7. What designs or methods did you see other teams try that you thought worked well?

8. How did you decide on the scale you would use to measure temperature with your device?

9. If you could improve the thermometer your family uses to take your temperature when you are sick what would you do? What features would you want to improve?

10. Provide an application where you think a particularly sensitive thermometer would be needed.

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
- Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

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

- Properties of objects and materials

CONTENT STANDARD D: Earth and Space Science

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

- Properties of earth materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understanding about science and technology

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

- Properties and changes of properties in matter

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

- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

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

- History of science

For Teachers:
Alignment to Curriculum Frameworks

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Matter and its Interactions

Students who demonstrate understanding can:

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or 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)**

Energy

- MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

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.

◆**Principles and Standards for School Mathematics (ages 6 - 18)**

Number and Operations Standard

- Instructional programs from prekindergarten through grade 12 should enable all students to:

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems

Measurement Standard

- Instructional programs from prekindergarten through grade 12 should enable all students to:

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

For Teachers:
Alignment to Curriculum Frameworks

◆**Principles and Standards for School Mathematics (ages 6 - 18)**

Representation

- Instructional programs from prekindergarten through grade 12 should enable all students to:
  - Create and use representations to organize, record, and communicate mathematical ideas
  - Use representations to model and interpret physical, social, and mathematical phenomena

◆**Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**

The Number System

- Apply and extend previous understandings of numbers to the system of rational numbers.
  - CCSS.Math.Content.6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.

◆**Standards for Technological Literacy - All Ages**

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope 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 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of 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.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies