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Teacher Notes

Calibrating Thermometers Introduction

Calibrating a thermometer is meant as an introduction to the use of digitally-based measurement tools in general and a temperature probe in particular. Students can sometimes view a probe as a "black box". In this activity they will be able to relate this new measuring tool to a known device, the standard liquid thermometer in a glass tube in the context of familiar values, for the boiling and freezing points of water.

There are four primary goals in this activity:

1. Students sometimes view measurement scales as arbitrary. This activity will enable students to see the relationship between the Celsius temperature scale and an everyday observable physical phenomenon, the boiling and freezing points of water.

2. In addition, students develop the concept that all measuring tools must be calibrated to a set standard based on a two-point scale.

3. As a result, they will begin to appreciate the need for accuracy and precision of readings from scientific equipment.

4. Finally, they will explore the advantage of digitally-based instruments in permitting more precise measurement.

The science content of the activity is built on observing the phenomena of the constant boiling point and the freezing point of water. In addition, students will gain familiarity and growing competence at using modern tools of scientific measurement and analysis. Part of this skill acquisition is becoming aware of the variables that might affect the accuracy and precision of scientific instruments.

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Discussion Guide

Begin a discussion with students about various measurement scales with which they are familiar. Probe their knowledge about how the scales were developed. For example, they may be aware that the foot became a standard unit based on the size of the king's foot.

Ask them to think about the American and metric systems of measurement. How are they different? Ask them why they think the metric system has been adopted by most countries in the world and is used exclusively in scientific measurement everywhere. (The primary idea is that it is far easier to compare different quantities or manipulate numbers using a system based on comparable units of 10.)

Pose the following scenario to the students: Sometimes we only want to know the approximate value, while at other times we want a more precise value. For example, when planning a trip to the supermarket we need to know about how much money to bring. On the other hand, when making change after a purchase we need to know the exact amount. The same is true in measurement. For example, when planning a trip we would want to know about how many miles or kilometers away our destination is in order to allow enough travel time. On the other hand, if we were manufacturing one of thousands of components on a tiny computer chip, the measurement unit would have to be much smaller! Ask students to brainstorm other such measurement comparisons.

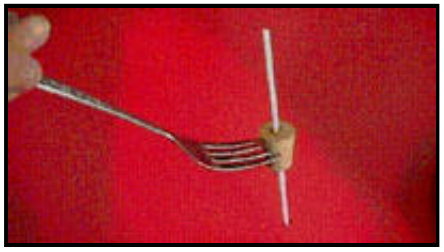
Pose the following problem to the students: Scientists needed to come up with a way to make sure that everyone around the world was using the exact same unit of measure for temperature. (We can't just choose any unit for temperature! How could they do this?) After some discussion, propose that a unique quality of a particular kind of substance is that it always has the same properties under the same conditions. Water is one of the most common substances on earth. Scientists discovered that it always boils and freezes at the same temperature. (This is only true under the same pressure for pure water.) They then decided to use a 100-point scale with 0 as the freezing point and 100 as the boiling point.

It is important to explain the purpose of a two-point calibration: that by knowing two points of a scale for certain, all other points between can be derived by dividing by equal parts until a specific point is identified.

Show the class a standard thermometer, an unmarked thermometer and a temperature probe. Propose that each device can be used as a measurement tool. Ask the class how we could check the accuracy of each tool. Direct the students to go to "Thinking About the Question".

- **Notes for Investigation I:**

Finding the boiling point should be a demonstration on the part of the teacher for each group. Since severe burns may result, the teacher should be careful while handling boiling water or working in the presence of steam. A fork is used to place the unmarked thermometer and cork in the boiling water.



Use the fork to move the thermometer outside of the path of the steam (with the bulb of the thermometer still in the boiling water) to mark the boiling point.

Care should be taken will placing the unmarked thermometer into the cork. If the fit is too tight, do not force the thermometer. It may shatter. Make the hole larger, but not so large that the thermometer will fall out of the cork.

- **Notes for Investigation II:**

Since the unmarked thermometers are so small, marking each of these divisions will be impossible---no matter how thin the markings. The students should decide on how small the divisions can be an still maintain accuracy. Remember the divisions must be in units of 10. One strategy might be to measure the distance in millimeters with a metric ruler from the boiling point to the freezing point. Another might be to divide this distance by two and mark your 50-degree point. This should be used as an opportunity to discuss the notion of the limits of particular measurement instruments.

- **Notes for Investigation III:**

There are a few key ideas that students can develop in this investigation. There will be variation in their temperature readings. That is great, because it affords the opportunity to discuss variables that might affect the accuracy and precision of instruments. In addition, students will be able to compare the reliability and precision of different tools leading to an appreciation for choosing the appropriate tool for the task.

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Additional Teacher Background

The scale we use for temperature is "degrees". There are three temperature scales that are used today. The Kelvin (degrees K) scale is used by scientists and for astronomical and gaseous temperatures. The Celsius scale (degrees C) is used in most of the world to measure air temperatures. In the United States, the Fahrenheit scale (degrees F) is used to measure temperatures at or near the surface.

All three temperature scales are related to each other through the "triple point of water". The triple point of water is the temperature at which water vapor, liquid water, and ice can coexist simultaneously at a certain pressure.

The students should begin to "think metric". However, because the United States uses the "English" system, they must become proficient in both systems. It is not important at this point to do conversions. Rather they should gain familiarity with metric units of measure through frequent usage. Think of it as being bilingual. When someone has fluency in more than one language they can think in each language. Having to do mental translations to make sense of the meaning of words or numbers is cumbersome and should be avoided.

While using scientific instruments, it is important that students identify the accuracy (reliability of readings) and the precision (reproducibility) of the readings.

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Calibrating Thermometers Suggested Timeline

The amount of time you spend on introductory discussions, data collection, and analysis, will determine your overall timeline. The following represents a possible timeline.

- One class period - Introductory Discussion
- One class period - Investigation I: Testing an unmarked thermometer in freezing and boiling water
- One class period - Investigation II: Creating a scale on your thermometer
- One class period - Investigation III: Testing different temperatures with your thermometer and temperature probe
- One class period - Analysis

Additional days can be used for further investigations.

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