Feeling and Measuring Temperature:
Can you believe your senses?

Grade Levels
Grades 2-4

Materials
- temperature sensor
- sensor interface
- thermometer (for teacher demonstration)
- plastic cups (about 400 ml, 12 oz)
- warm and cool tap water
- paper or cardboard sheet for fan 21 cm x 28 cm or 8 1/2 in x 11 in

Teacher Introduction

Overview
In this investigation, students use a temperature sensor to compare the feeling of temperature with the result of a measurement. They investigate still air, moving air, and water temperatures.

Learning Goals
Students will gain experience with both inquiry skills and content, including:
- realizing temperature’s effect on matter.
- understanding that properties of matter are dependent on outside conditions including temperature.
- understanding that heat flows from a warmer to a colder object until they come to the same temperature (equilibrium).
- understanding that humans and other organisms have senses that help them detect internal and external cues.
- planning and conducting a simple investigation.
- using data to construct a reasonable explanation.
- understanding the process of measurement and units.
- making explanations and predictions from evidence and drawing logical conclusions.
- gaining skills and confidence in using a scientific measurement tool, the temperature sensor, as well as the graphing capacity of a computer to represent and analyze data.

Vocabulary
Activity adapted from Technology Enhanced Elementary and Middle School Science (NSF–Grant No. IMD0352522).
Engage

Discussing our senses

Start the discussion with the question,

*Can you believe your senses?*

Keep coming back to this question throughout the investigation. You might elaborate on the question by asking students to break it into sub-questions, such as:

*What are your senses?*
*What does each sense detect?*
*How does our brain find out?*
*What does it mean to believe our senses?*
*Are there times when our senses are not accurate?*

To answer these questions, it might be helpful to start by asking the students to think about what they can sense, where they sense it, and how their brains get information from their senses. The five main senses are hearing, sight, taste, touch, and smell. It is often assumed that these are the only senses, but there are more. We also sense hot and cold, balance, and pain. For a nice source of information on hearing, sight and taste see http://www.hhmi.org/senses/.

Introducing students to the temperature sensor

Ask students to make a list of electronic devices that measure what we can sense, such as light, heat, and sound. Have them discuss whether the electronic sensors would provide the same information as our senses, and if not, why not. Students may not believe the sensor measurement, especially if it seems to be different from their sensation. Since they may have more experience with a bulb-type thermometer, you should demonstrate the conventional thermometer and the electronic sensor side by side, to show that they measure the same thing. Direct the students to “Thinking About the Question.”

Activity adapted from Technology Enhanced Elementary and Middle School Science (NSF–Grant No. IMD0352522).
Thinking About the Question

The main point of the Activity 1 is to get used to using the equipment. Once students are comfortable collecting data and taking notes, they will eagerly measure temperatures and try to make the graphs change within their groups. Ask students to decide how long it takes to get an accurate measurement. When you first start measuring, the reported temperature changes, but then it reaches a steady value. This is because it takes time to warm or cool the sensor. Some sensors require only a few seconds, while others need much longer. In the experiments that follow, students should be aware of how long they must wait before making a reading.

Activity 1

There will probably be a considerable range of skin temperatures throughout the class. It's normal for our skin temperatures to vary a lot, even though the temperature inside our bodies varies just a little. That's why the thermometer is usually put under your tongue when the doctor takes your temperature.

Activity 2

In the next two activities, two situations are used to highlight the difference between the measured and the perceived temperature. First, students discover that moving air cools their arm, but the moving air itself is not cooler. They are asked to make a prediction of the temperature of the moving air before making the measurement. Focus attention on these predictions without telling students the right answer. Get them committed to their predictions by writing down the results. Then, when they have found no temperature difference between still and moving air, return to the predictions.

Activity 3

Next, students discover that water at room temperature feels colder than air at the same temperature. Again, stimulate thinking by asking students to justify their predictions before they do the experiment. Have the class vote and write the results. Most will think that the two will feel the same.

Don’t give away answers

It is important to avoid telling students what we think that they should discover. Instead, keep asking them what they have observed; what the experiment revealed. When there is a conflict between what they believe and what they observe, it is only human to ignore the observation and stick with long-held beliefs. So, while students observe that moving air is not cooler than still air, they will cling to the idea that it is cooler. They will also believe that if water feels colder than air, it must have a lower temperature. Only through reflection and discussion will they understand why measuring and feeling are different.

While our senses are vital to our survival, they may be misleading in a scientific investigation. It is useful to have students reflect on the similarities and differences between the temperature we sense and the one we read with a temperature sensor or thermometer.

Concluding Class Discussion

In summation, you can start a discussion about this by asking: “Why is an electronic sensor better for measuring than our senses?” Perhaps the most important is that electronic sensors give a number and our senses simply give sensations. “A cool day” to you might be “warm day” to someone in Alaska, but 15 degrees Celsius is the same everywhere.

Ask students,

How are human and electronic sensors different?
Following are possible answers: A sensor can sometimes measure smaller differences than we can. It can sometimes measure faster. A sensor can also be less perceptive or slower than human senses. For example, if our fingers were as slow to respond as a temperature sensor, we’d be in trouble!

Remind the students that senses and sensors measure different things. A thermometer measures absolute temperature and our fingers sense the difference between our body and our surroundings.

A sensor can “remember”. It can display a time graph so that you can watch things change and find a pattern. A sensor will measure the same value in the same situation, again and again. This is valuable for scientific investigation. On the other hand, human sensation may change depending on the setting and previous experience. It may vary from person to person. Sensors give numerical values instead of feelings like “cool” or “warm”, which can vary for different people and different times. You might be able to feel that A is warmer than B, but “how much warmer” would be hard to express without numbers.

Here are some other questions you might use to stimulate discussion:

Suppose I discover something. I want you to copy my experiment, so I need you to do exactly what I did. What is the best way to tell you about the temperature in my experiment?

Are there cases where an instrument can measure something you cannot sense?

Are there cases where our senses are better than an instrument?

Background Information

Feeling temperature vs. measuring temperature

There are special nerves in the skin that sense hot and cold—different from the nerves that sense pressure or pain. Different parts of the body are more and less sensitive to temperature. To explore this, touch your skin with an ice cube wrapped in plastic. Try your finger, inner and outer arm, forehead, leg, and cheek. There are many situations where the body and the temperature sensor don’t give the same results. The reason is that they measure different things. The temperature sensor measures the absolute temperature, but the skin senses the difference between its own temperature and the environment, because that’s what matters to our body.

If the surroundings are colder than the skin and the conduction of heat away from the skin is increased, then the skin cools down and the body detects coldness. Examples include moving air (Activity 2), which carries heat away better than still air and water (Activity 3), which conducts heat much better than still air. Also, the feeling of a room temperature metal surface, which conducts heat away from the skin very quickly and will feel very cold, compared to a room temperature wood surface, which is less of a conductor and will feel warmer. Another example is bare skin, compared to skin insulated with clothes or blankets or dry clothes, compared to wet clothes.

The reverse is also true. If the surroundings are warmer than the skin and conduction is increased, then the skin heats up and the body detects warmth. Examples include hot water which is much more dangerous than hot air, again because water conducts better than air. For this same reason, the air in an oven might be above 100 degrees C. It will make your hand feel hot, but won’t instantly burn it, as boiling water would. Another example is a cloth hot pad that protects your hand from the hot metal handle of a frying pan, which would conduct heat very quickly to your skin and burn it.
**Temperature sensor**

The temperature sensor detects the absolute temperature, because it is designed to do that. “Temperature” has a specific physical meaning that scientists have agreed upon: the kinetic energy, or energy of motion, of the molecules. Thermometers have been made to measure this in a consistent way, so that scientists working all over the world, in many different experimental situations, can understand and repeat each other’s results. The thermometer is a very important scientific tool.

**Celsius and Fahrenheit**

This investigation is written using Celsius (degrees C) temperature units. In the Celsius system, water freezes at 0 degrees C and boils at 100 degrees C. This scale may be difficult for students who are used to the Fahrenheit (degrees F) system, for which water freezes at 32 degrees F and boils at 212 degrees F. You may spend some time comparing these scales if you wish, but it’s not necessary for the investigation, which uses bar graphs as well as numerical values to display temperature.

**Cooling by evaporation vs. cooling by moving air**

Cooling by evaporation is different from cooling by moving air. Students have experienced both and probably think they work the same way. Unlike moving air, evaporative cooling affects both the skin and the temperature sensor. When you wave around a wet finger or a wet temperature sensor, the water molecules evaporate into the air, cooling off the surface. It not only feels cooler, it is cooler. In very hot weather, or when we are working hard and our muscles produce a lot of heat inside our bodies, we cool off by sweating: our skin secretes water, which then evaporates and cools us.

**Body temperature control and climates**

The feeling of hot and cold is essential to survival. All animals face changes in the temperature of their surroundings that are greater than their bodies can tolerate. For instance, the interior of our bodies must stay close to 37 degrees C for us to stay alive. Animals must be able to detect the surrounding temperature and have strategies for maintaining their proper body temperature. Here are some examples, and students can think of others: Many mammals have hair or fur that creates a thin layer of still air near their skin, which is a better insulator than moving air. Musk oxen and polar bears have heavy fur coats with several layers of fur that keep them warm even in winter in the far north.

When our skin temperature gets too high, we sweat and the evaporating water cools us down. Some fur animals, like rabbits, lose extra heat from their ears.

Whales and seals have layers of fat (blubber) that insulate them from cold arctic waters. Water birds like ducks have oil in their feathers that keep the water away from their skin. Cold-blooded animals, like reptiles and insects, take different approaches from warm-blooded animals, such as mammals. Their body temperatures are not as constant, and their activity level often changes depending on the temperature.

One reason that people can live all over the world, and many animals cannot, is that people can make themselves clothes that protect them from heat, cold, and wet.
Time Required
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-half class period** Introductory Discussion—Engage
- **One class period** Activity 1: Measuring Arm Temperature
- **One class period** Activity 2: Comparing Still and Moving Air
- **One class period** Activity 3: Compare Air and Water
- **One class period** Analysis–Summary

Extensions for Students
- Fool your fingers. Make three pitchers of water—one hot, one cold, and one medium. Put one hand in the hot water and one in the cold. Wait for one minute. Put both hands in the medium water. Does it feel the same to both hands? Measure the three pitchers with the temperature sensor. Can you explain what is going on?

- With your finger, touch several materials that have been sitting in the classroom for a while: wood, plastic, metal, glass. Do they all feel the same temperature? Then measure each one with the temperature sensor. Use tape, and not your fingers, to hold the sensor against the material. Do the materials measure the same temperature? What do you think is going on?
Feeling and Measuring Temperature

Name __________________

In the 3 activities you will investigate the feeling of temperature and compare it to what is measured by a temperature sensor.

Thinking About the Question

In the activities, you will use an electronic sensor to measure temperature. It is a kind of thermometer. Your teacher will show you the electronic temperature sensor and a regular thermometer side by side. They give about the same result.

1. Our skin is very sensitive to temperature. We often use our fingers to sense how hot or cold something is. What if you couldn't feel hot or cold? What problems would that create for you? Discuss this with your group and write down your ideas.

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_________________________________________________________________
_________________________________________________________________
2. What if you touched two things and it felt like they were different temperatures, but a thermometer measured the same temperature for both. Which would you believe, your finger or the thermometer?

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_________________________________________________________________

New Words

Climates ________________________________

Electronic Sensor __________________________

Investigate ____________________________

Measurement ____________________________

Prediction ____________________________

Sensitive ______________________________

Sensor Interface __________________________

Temperature ____________________________

Thermometer ____________________________

Investigating the Question

Do the 3 activities in this section

   Activity 1: Measuring Arm Temperature
   Activity 2: Compare Still and Moving Air
   Activity 3: Compare Air and Water
Activity 1: Measuring Arm Temperature

Name _____________________

Materials
- temperature sensor
- sensor interface

Steps
1. Use the temperature sensor to measure the air temperature. You will need to wait a little while until the temperature stops changing.

   The air temperature is __________

2. Measure your arm temperature. Hold the temperature sensor against your skin with your finger. You will need to wait a little while until the temperature stops changing.

   My arm temperature is __________

3. Measure the arm temperature for each person on your team.

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<th>Person</th>
<th>Temperature</th>
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What do you notice? What is the biggest difference you found?

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4. Measure the temperature of the air again. You may have to wait for the temperature to stop changing. If the temperature changed, why do you think it did?

The air temperature is __________

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_________________________________________________________________

5. Measure the temperatures of a few other things—you think are interesting. Write down what you find.

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<tr>
<th>Object</th>
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Activity 2: Compare Still and Moving Air

Name _____________________

Materials
- temperature sensor
- paper or cardboard
- sensor interface

Steps
1. Think about how your bare arm feels in still (not moving) air.

2. Make air move across your arm by waving a piece of paper or cardboard back and forth, like a fan. How does moving air feel on your arm compared to still air? Does it feel warmer, cooler or the same?

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_________________________________________________________________

3. Now let’s see if there is a change you can measure. Measure the still air temperature. You will need to wait a little while until the temperature stops changing.

   The air temperature is __________
4. Now wave your paper fan to make air move across the temperature sensor and measure the temperature again. You will need to wait until the temperature stops changing.

The air temperature is __________

5. Compare the temperature of the still air with the temperature of the moving air. Was there a change? Why?

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_________________________________________________________________
_________________________________________________________________

6. If there was a change of less than one degree, do you think it is important? Why?

_________________________________________________________________
_________________________________________________________________

7. Remember how the still and moving air felt on your arm. Did they feel different? Look at the temperatures you measured. Are they different?

8. Is there a difference between the feeling of temperature, and the measurement of temperature? If there is a difference, how would you explain it?

_________________________________________________________________
_________________________________________________________________
Activity 3: Compare Air and Water

Name

Materials
• temperature sensor
• plastic cups
• warm and cool water
• sensor interface

Safety
Avoid hot water. It may burn you.

Steps
1. Your teacher will give you some warm, some cool water, and a cup. Your task is to mix them until the water in your cup is the same temperature as the air.

2. If you measured the water temperature and the air temperature and they were the same, do you think they would feel the same? Would the water feel cooler, feel warmer, or the same as the air. Why do you think this would be true?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

3. Now test your prediction. Measure the air temperature. You may need to wait a little while until the temperature stops changing.

Air temperature is __________

4. Mix warm and cool water in your cup, mixing and measuring with the temperature sensor. Stop when the water temperature is within one degree of the air temperature. That's close enough!
5. Put your finger into the water. How does water feel on your finger compared to air? Did the water feel cooler, warmer, or the same as the air?

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6. Is there a difference between the feeling of temperature, and the measurement of temperature?
   *Hint: think about what the water does to your finger, compared to what it does to the temperature sensor.*

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Feeling and Measuring Temperature:
Can you believe your senses?

Name __________________

Answering the Question
In the 3 activities you studied the feeling of temperature and compared it to what is measured by a temperature sensor. Now answer these questions.

1. Your feeling of temperature can change when the measurement of temperature does not change. For example, even though the moving air is the same temperature as the still air, it feels colder. How can you explain this?

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2. If you were doing a science experiment, which would be better for measuring temperature -- using your finger or a temperature sensor? Why?

_________________________________________________________________
_________________________________________________________________
3. Animals in cold climates have heavy coats. Water birds have lots of oil in their feathers. How do your tests explain why these features help the animals stay warm?

*Hint: think about how moving air feels colder than still air, and water feels colder than air.*

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4. What if you touched two things and it felt like they were different temperatures, but a thermometer measured the same temperature for both. Which would you believe, your finger or the thermometer? Explain your answer.

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