Thermometer Technology[1]

Additional files and links

- Image and talking-points slides
- Take-home activities
- 15' tutorial, *available in September*

Reviewers

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Activity Inspiration

- Our thermometer assembly and testing protocol was inspired by Science Buddies

[1] This was developed for a 10-week after school program with our local Boys & Girls Club. This was run with 16 groups of K-5 students (blended age groups). Each group was facilitated by 2-3 JMU students who are members of the JMU STEM Corps. Groups were fairly consistent across the 10 weeks. The lesson started at 3:45 on a Friday and wrapped up by 5PM. See more here.

Overview for Facilitators

Technology ideas: This is the 1st lesson on the role of technology in STEM, starting with how scientists use technology to acquire new knowledge and make discoveries. These lessons are designed to encourage students to ask questions about technology such as, *which technology should I use?* and *how does it work*? The first 2 lessons challenge students to build and test a simple version of a real instrument used for sensing and measuring energy. By using familiar materials and constructing a simple design, we can focus their attention on the basic mechanism and underlying science principles of the technology. This week they will build a simple liquid thermometer and next week they will build a simple anemometer for measuring wind speed.

Science ideas: After building their liquid thermometer, students will use it to observe the relationship between energy and movement. Specifically, they will see that moving their thermometer from room temperature water to warm water causes the liquid to move up the straw while moving it to cooler water causes the liquid to drop down the straw. The science behind this is a middle-school level concept in VA. While these ideas are not key learning goals for our K-5 audience, we want facilitators to understand the phenomenon so they feel confident in their own understanding and ability to address questions[2]:

- When the thermometer is placed in an environment with more thermal energy (the warmer water), some of that thermal energy is transferred to the thermometer.
- That increase in the thermometer's thermal energy causes fast movement of the liquid molecules causing them to move further apart from one another (see side 2 of grade 3-5 take-home activity here). Because our space for this movement is the narrow column of a plastic straw, the liquid rises up the straw.
- In contrast, when the thermometer is moved to cooler water, some of the thermometer's thermal energy is transferred away from the thermometer to the cooler water.
- The decrease in the thermometer's thermal energy decreases movement of the liquid molecules causing them to get closer together, resulting in the liquid dropping down the straw.

While some students may not have the background knowledge and skills to grasp the connection between thermal energy and movement of liquid particles, our goal is to make this experience fun and memorable, so students will make connections back to this experience when learning about thermometers and temperature units in 4th grade and about energy as "the ability to do work" in 5th grade.

Science practices: Incorporated into all of our lessons are opportunities to demonstrate key differences between science and engineering. Starting with this lesson, we highlight the difference between building and testing working models for understanding, a practice commonly associated with science, and the engineering practice of designing and building a novel design to address a problem or challenge. Facilitators should not refer to the thermometer assembly as a design challenge or engineering practice. In addition to the model-building practice of this lesson, students will carry out an investigation using the thermometer to measure the *relative* difference in thermal energy between cold, room-temp., and warm water. While this simple technology cannot provide data in degrees, it will allow students to test their predictions and make conclusions. They will then represent those conclusions visually in the take-home activity. By talking to students about their visualization and how they will explain it to their family, you can check for understanding and address any confusion or lingering questions.

[2] You can learn more about this from the American Chemical Society.

Lesson Flow

Page	Description	Items needed
Full-group introduction led by SLIs		
-	• Interest-piquing intro & LF prep.	
Small-group discussion		
-	• Measuring tools • Thermal energy • Reading a thermometer	Slides 1-4 with talking points
Part I. Assembling the thermometer		
4-6	• Prepare colored liquid • Assemble thermometer apparatus • Create the liquid column	• vial of alcohol, cup • food coloring, dropper • air-dry clay, plastic
Part II. Thermometer investigation		
7	• Observe movement & mark liquid height in cold water. • Check for understanding	• Thermometer • timer (phone) • 3 plastic containers • tube of room temp. water • cool and warm water from SLI station • alcohol-resistant marker
8	• Observe movement & mark liquid height in room-temp. water. • Check for understanding	
8-9	• Observe movement & mark liquid height in warm water. • Check for understanding*	
Part III. Data collection*		
10-11	• Measure and record markings	Data sheet, ruler, pencil
Part IV. Take-home activity and discussion*		
11-12	• Explain, talk about it, ask parent prompt questions.	Crayons, take-home activity.

*= differentiated for K-2 and 3-5

Step-by-Step Guide

Safety Precautions

This activity uses 80% isopropyl alcohol. Safety precautions are provided to prevent students from splashing or spilling the alcohol. To minimize this risk of the alcohol coming into contact with their skin or eyes, **you will**:

1. Allow the students to take turns doing all tasks **except** steps involving removing or replacing the lid on the vial of alcohol (highlighted below)
2. Make sure students are seated in their chairs and paying attention throughout the lesson.
3. Remove anything with rubbing alcohol from the table before Part III .

Part I. THERMOMETER ASSEMBLY

You will need: vial of alcohol, straw, food coloring, clay, plastic cup, dropper, & paper towels.

1. **Students will prepare the seal for the thermometer** (Fig. 1):

   - ☐ Mold *one* clay piece into a round shape that is larger than the neck of your bottle[3].
   - ☐ Make a hole in the middle of the clay, just big enough for the straw to pass through. Place the straw through the hole.
   - ☐ Remove any clay clogging the straw. Set aside.

2. **LFs will help students add food coloring to the alcohol:**

   - ☐ **LF will** carefully remove the lid and hold the vial steady for students.
   - ☐ **Students will** add **2-3** drops of food coloring to the alcohol in the vial so it is dark enough to see easily through the straw.
   - ☐ **LF will** replace the lid, tighten, and invert to mix[4].

[3] We tried air-dry clay (Model Magic™) and modeling clay. We recommend air-dry clay because it forms a tighter seal around the straw allowing the column to form, however, if it gets wet, the seal will loosen.
[4] We used scintillation vials because we have them in our collection. The Science Buddies lesson we adapted suggests “any clear, narrow-necked, small bottles” such as these.

3. **Students will learn how to use dropper then remove some of the colored alcohol[5].:**

   - ☐ **LF will** remove the lid and demonstrate how to fill the dropper: Squeeze the bulb, place the dropper into the liquid, slowly release your squeeze on the bulb, Dispense the liquid back into the vial by slowly squeezing the bulb.

   - ☐ While LF is holding the vial steady, students will do the same but instead of dispensing back into the vial, they will dispense the removed liquid into the the plastic cup[6].

   - ☐ Repeat 3 more times, each time transferring a full dropper of liquid. You will use this removed alcohol in step 5[7].

4. **Students will attach the straw & clay to the uncapped vial**:

   - ☐ Place the straw into the alcohol so that the end is immersed in the liquid, but does not touch the bottom of the vial (Fig. 2).

   - ☐ Mold the clay tightly around the neck of the bottle. ***Make sure the clay forms a tight seal around the straw and bottle*.**

5. **Students will fill the straw with the removed alcohol to create a column:**

   - ☐ If not already, place the bottle on a paper towel to catch spilled liquid.

   - ☐ Following the same practices used in step 3, use the dropper to slowly add the liquid from the plastic cup to the straw.

   - ☐ Do this until the liquid level is at least halfway-up the visible part of the straw (Fig 3). *Expect them to have trouble getting it all into the straw; the straw is narrow compared to the dropper. Help as needed.*

[5] This step is not necessary if you provide a separate vial of the liquid. We had the students do this step of using the dropper to remove liquid from the vial and place it in a separate cup to provide an opportunity for students to practice using the dropper before using it with the narrow-opening of the straw.
[6] Paper cups do not work well because they absorb much of the alcohol.
[7] The number of transfers depends on the size of the dropper. We used 1ml (4 in.) glass droppers because we have them in our collection. We recommend students remove enough liquid to create a column that comes half-way up the visible part of the straw.

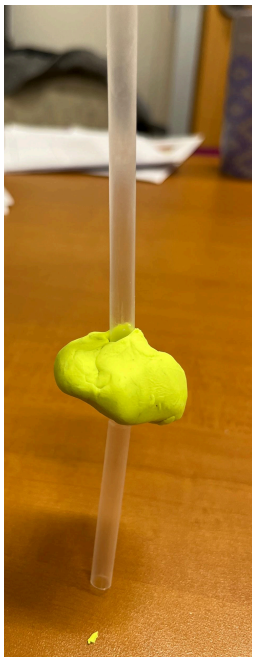
Figure 1. Step 1.

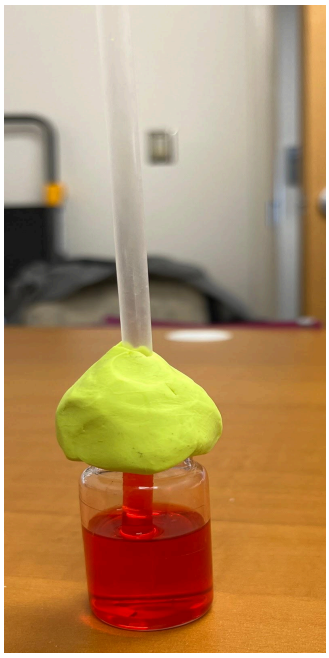
Figure 2. After step 4.

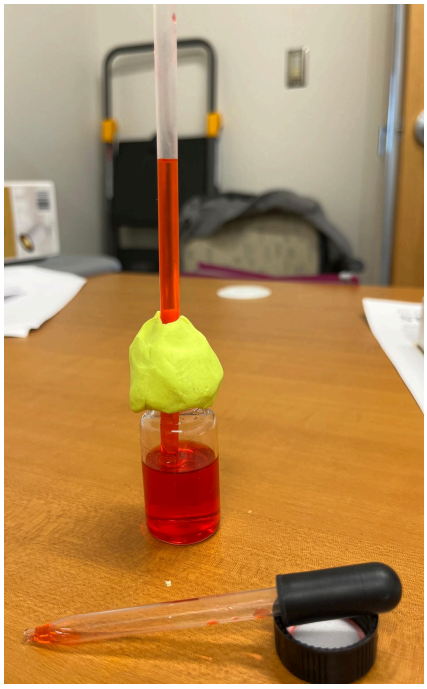
Figure 3. After step 5.

Trouble-shooting:

- If the added liquid isn't at least half-way up the visible part of the straw or is dropping down the straw, it likely means the clay seal wasn't formed tightly or the model magic got wet in the process.

- If this happens, disassemble the apparatus and go back to step 1 using your back-up piece of Model Magic. It is important to take the time to rebuild the thermometer and make sure the seal is tight enough. Otherwise, the investigation with different water temperatures will cause confusion and disengagement. Ask SLIs if you need extra materials.

Part II. THERMOMETER INVESTIGATION

You will need: 3 shallow plastic containers[8] (our "water baths"), tube of room–temp. water, alcohol-resistant marker, timer on phone. Let SLIs know when you are ready for the warm and cold water.

1. **Students will observe movement and mark liquid height in cold water.**

   - ☐ To one of your three water baths, add cold water.

     You want enough water that half of the vial will be submerged when placed in the water bath but not so much that the water touches the clay seal.

   - ☐ Ask students to gently (to avoid spills) place their finger in the water so they feel that it is cold (or at least cooler than the air around it).

   - ☐ Place the thermometer in the cold water bath, set the timer for 60 seconds, and observe. After 60 seconds, the liquid should have stopped moving unless there is a break in the seal.

   - ☐ While LF holds the thermometer steady, students will use the alcohol-resistant marker to draw a line on the straw marking the top of the liquid. Make sure it is visible because they will measure the distance between the bottom of the straw and this line later.

   - ☐ **Leave the thermometer in the cold water** until you are ready to move it to the room-temp. water in step 3.

2. **Check for Understanding**

   - ★ Ask students to describe what they observed and where the liquid went.

   - ★ Ask students how this is like a real thermometer. You can refer back to slide 4 to help them make these connections.

   - ★ Ask students what they predict will happen when they place the thermometer in water that is the same temperature as the room (in general and/or you can ask how high the liquid will rise).

[8] We found that Greek yogurt containers or food storage containers of similar size and shape work well.

3. **Students will observe movement and mark the liquid height in <u>room-temp.</u> water.**

   - ☐ Using the tube of water in your bag, add the same amount of water to a new container.
   - ☐ Ask students to gently place their finger in the water to feel the relative temperature compared to the first water bath.
   - ☐ Move the vial directly from the cold water to room-temp. water, set the timer for 60 seconds, and observe.
   - ☐ Use the marker to mark the height of the liquid in the straw.
   - ☐ **Leave the thermometer in the room-temp. water** until you are ready to move it to the warm water in step 5.

4. **Check for Understanding:**
   - ★ Ask students to describe what they observed and whether or not their observations matched their predictions.
   - ★ **For grades 3-5**, ask what made the liquid move up the straw.
     The thermal energy or heat in the water. Even though the water didn't feel warm or hot when we touched it, it is warmer than the cold water, which is because this water has more thermal energy than the cold water.
   - ★ Ask students what they predict will happen when they place the thermometer in warmer water.

5. **Students will observe movement and mark the liquid height in <u>warm</u> water**
   - ☐ To your third container, add the same amount of warm water from the SLI station.
   - ☐ Ask students to gently place their finger in the water to feel the relative temperature.
   - ☐ Move the vial directly from the room-temp. water to the warm water, set the timer for 60 seconds, and observe.
   - ☐ Use the marker to mark the height of the liquid in the straw.
   - ☐ **Leave the thermometer in the warm water**.

Check for Understanding

★ Ask students to describe what they observed and whether or not their observations matched their predictions.

★ **For grades 3-5,** ask what made the liquid move up the straw.

★ Ask students what we could do to our water bath if we wanted the liquid to rise even higher in the straw?

E.g., heat the water in a microwave or insulate it by wrapping it in something like aluminum foil or material used for winter coats, etc.

6. LF will disassemble the thermometer to prep for part III:

☐ Remove the straw from the bottle and clay seal.

☐ Allow the liquid from the straw to collect in the bottle and wipe the straw down with a paper towel.

☐ Lay the straw on a clean paper towel.

☐ Set the rest of the thermometer materials aside and out of the way.

Part III. DATA COLLECTION GRADES 3-5

You will need: scrap paper, pencil, ruler, data sheet.

1. **Students will demonstrate their measurement skills using a standard ruler.**

   - ☐ **LFs will** draw a line that measures x inches (any whole number). Ask students to show you how they use the ruler to measure length in inches (*first grade Math standard).*

   - ☐ Once they are comfortable with that, draw a line that is in between two whole numbers and see how comfortable they are with measuring to the nearest inch. (*2nd grade Math standard*).

     Listen to how they describe fractions of inches (e.g. "between 4 and 5", "close to the 4", "4 and a half"). Use that language as you work through the measurements in step 2.

2. **Students will measure and record distances between the bottom of the straw and the three liquid lines.**
   - ☐ Measure length to the nearest inch, have them take turns measuring the distance of each of the three lines from the bottom of the straw (the end that was in the vial). **Record the measurements on the data sheet**.

PART IV. TAKE-HOME ACTIVITY GRADES 3-5.

Ask SLIs for the Spanish version

1. Instruct students to color the straws to represent the data.

2. As they are coloring or when they are finished, read the family statement and ask them to tell you how they will answer the questions.

3. Provide positive feedback and help fill in any gaps in their memory of what they did or their understanding of key concepts.

4. If there is time, they can complete side 2. Otherwise, explain the instructions (emphasizing the use of two different colors, one for fast-moving particles and one for slow-moving) before they leave and encourage them to finish it at home.

Part III. DATA COLLECTION GRADES K-2

NOTE: In grade 1, students learn to measure length using nonstandard units- usually objects like popsicle sticks or cubes. The rules they are taught: the units must be the same, they can't overlap, and there can't be space between them. For this activity, we will use a nonstandard ruler with pictures of cartoon monkeys.

1. **Students will demonstrate their measurement skills using a non-standard ruler** (see slide 10 here).

    - ☐ **LFs will** draw a line that is x monkeys long (whole number) and ask students to use the ruler to tell you how many monkeys long the line is. Help students as needed.

    - ☐ Once students are comfortable with the above, draw a line that stops in the middle of a monkey, ask them to measure the line and listen to how they describe it (e.g., if they refer to a 3.5 monkeys line as "3 monkeys" or something more specific).

        The purpose of this is to understand how they see it and learn to talk about it so you can use that language with them in step 2 below.

2. **Students will measure and record distances between the bottom of the straw and the three liquid lines.**

    ☐ Once your group is comfortable with the above, have them take turns measuring the distance of each of the three lines from the bottom of the straw (the end that was in the vial).

    ☐ Record the measurements on the data sheet.

PART IV. TAKE-HOME ACTIVITY GRADES K-2.
Ask SLIs for the Spanish version.

1. Instruct students to color the straws to represent their measurement data.

2. As they are coloring or when they are finished, read the family prompt and ask them to tell you how they will answer the questions.

3. Provide positive feedback and help fill in any gaps in their memory of what they did or their understanding of key concepts.

4. If there is time, they can complete side 2. If not, make sure they see it and encourage them to complete it at home.

Clean-up Instructions

Encourage **students to help by giving them one of the jobs in blue**. LFs should do the other tasks.

1. Rinse the dropper by drawing up and releasing water (in one of our water baths) a few times.

2. After the above is done, use the funnel to pour alcohol from the vial and water from water-bath containers into the liquid waste cup.

3. Take this cup to SLI station and dump liquid into their large waste collection container for proper disposal.

4. Toss straw and paper towels into the trash.

5. Toss or recycle lesson guides.

6. Toss broken crayons, return good crayons and pencils to the pencil box, make sure it is closed.

7. Return slides and unused activity docs to the folder with paper clips.

8. Place these items back in the bag:
    - Alcohol-resistant marker
    - Empty glass vial with capped lid
    - Bottle of food coloring with lid
    - Dropper- rinsed
    - Empty water-bath containers
    - Pencil box with crayons and pencils.
    - Rulers
    - Unused air-dry clay
    - Funnel

9. Clean table with disinfectant wipes and/or paper towels.

10. Provide hand wipes (*not* disinfectant wipes) from SLI station for those who want to clean their hands.

Materials

Each group gets a 2.5-gallon freezer bag with zipper lock with materials and a folder printed documents.

* = extras of these will be included in SLI boxes.

In each bag

- Straw (1)*
- Plastic bag with 2 balls of Model Magic (air-dry clay) (1)*
- Capped vial filled with isopropyl rubbing alcohol (1)*
- Small bottle of water-soluble food coloring (1)*
- Alcohol-resistant black marker (1)*
- Dropper (1)*
- Small plastic cup (1)*
- Shallow plastic containers (water baths) (3)*
- 50 ml tube filled with water (1)*
- Paper towels (2 full sheets)*
- Pencil box with pencils and crayons*
- Standard ruler (1)*
- Non-standard ruler (1)*
- Funnel to help with clean-up (1)
- Large plastic cup labeled, “waste”.

In each folder

- Pages 3-13 of lesson guide (2)*
- Discussion docs: 4 image slides with text on back/paper clipped (1)*
- Data table (1)*
- 2-sided take-home activity (1 per student), differentiated*.

SLI station

- 1-2 extras of every item with a *
- Thermos of warm water
- Cooler of ice water
- Disinfectant wipes
- Hand-wipes
- Spanish versions of take-home activities

Possible extension activities

Engineering Design Practices and Integrations

1. Using this teachengineering.com resource as inspiration,challenge students to design an insulator for the water bath and use their thermometer to test their design. Together, these experiences can be used to expose students to how scientists can use technology (the thermometer) to acquire new knowledge (this lesson) *and* to how engineers use technology to test their design prototypes (this extension). You could then build on these ideas with our second lesson on wind speed technology, which introduces students to how engineering can improve technology by making it easier for scientists to use and more accessible to the general community.

Physical Science Enrichment

2. Have students explore real liquid thermometers using this collection of teacher resources from the American Chemical Society.

Sources used in lesson development

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8. Hurst, M.A., Polisnky, N., Jaden, C.A., Levine, S.C., Uttal, D. Leveraging Research on Informal Learning to Inform Policy on Promoting Early STEM (2019). *Society for Research in Child Development, Social Policy Report.* https://doi.org/10.1002/sop2.5