Inquiry Lesson Plan

I. Rationale/Purpose:

Standards & Context:

Topic: Temperature & Specific Heat
Grade Level: 9th-12th
NGSSS Standards:

- SC.912.P.10.5 - Relate temperature to the average molecular kinetic energy. Recognize that the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy.
- SC.912.P.10.4 - Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter.

Purpose

Students should learn the material in these standards, and in this lesson, because the concepts herein deepen understanding of everyday phenomena. Students may have many misconceptions about thermal energy due to misinterpretations of their everyday experiences with temperature and heat. A deepened understanding of temperature, specific heat, and the movement of thermal energy will enrich their understanding of the world around them and improve their ability to interact with the world in meaningful ways that reflect the "practices of science" goals as put forth by the NSTA, such as "Constructing Explanations and Designing Solutions," (National Science Teachers Association, 2014) which students do when they are led to explain the difference between their expectations and the actual outcomes. Depending on their choice of exit assignment, the students also engage in "Obtaining, Evaluating, and Communicating Information" by writing an essay, or "Planning and Carrying Out Investigations" by planning an experimental procedure (National Science Teachers Association, 2014).

By engaging with this lesson students are prepared to better understand heating and cooling systems, insulation, cooking, and countless other thermal concepts in their lives. Students will also be better prepared to understand higher-level concepts relevant in science and engineering studies in higher education courses, including a

better general understanding of forms of energy and energy transfer, which is a crosscutting concept in all STEM fields.

Learning Goal:

Students will have an enriched understanding of perceived temperature (temperature relative to our body heat) and be able to compare it to actual temperature (average thermal energy in an object). Students will also recognize that specific heat and thermal conductivity play a role in perceived temperature differences that complicates our subjective perceptions of temperature.

Objectives:

1. **Content -** Through experimental observation (touch and measurement) of several different materials (wood, acrylic and aluminum), students will be able to distinguish between the perceived temperature of an object and its average thermal energy, and explain the role of specific heat and conductivity in the perception of temperature.
2. **Language/Literacy** - Students will be able to explain the experimental procedure, observations and conclusions in their own words, using scientific language. Students developing literacy skills will be able to complete a "Claim-Evidence-Reasoning" template using complete sentences in order to communicate their experimental findings to their peers.

Essential Questions

1. Is temperature a property of a material?
2. Can we compare the temperatures of two objects by touching them?

II. Misconceptions:

- "Temperature is a property of a particular material or object. (For example, students may believe that metal is naturally cooler than plastic)" (Fries-Gaither, 2009).
- "When two objects at different temperatures are in contact with each other, thermal energy is transferred from the warmer object to the cooler object and 'coldness' or 'cold energy' is transferred from the cooler object to the warmer object (AAAS Project 2061, n.d.)" (American Association for the Advancement of Science, 2017).

III. Detailed Procedures:

Engage

- **Using the website https://answergarden.ch/, Students will be asked to provide in their own words a definition to the word "Temperature"**

    - Teacher will address the most popular answer submissions in a class discussion before presenting the class definition of Temperature to the students.
    - If needed, students may also use Google Translate to assist them in finding a definition.
- **Definition of "Temperature" from Google displayed on the board**: "*Temperature - the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch.*"
    - Teacher reads it clearly out loud as well as leaving it on the board. If 1-to-1 technology available, then students with very low English language proficiency may also look up the definition in their native language.
- **Ask students if they agree with this definition**. Lead them to discuss with their groups and, in their science notebook, write: ***(5 minutes)***
    - Their own definition of temperature.
    - How do we measure an object's temperature?
    - What makes an object hot?
    - What makes an object cold?
        - Students may choose to add drawings to help add to their explanations.
        - Each group provided with a worksheet that also has the questions, if they need to refer back to the prompts later.

Explore

1. **Divide students into groups**
    a. The number of groups should match the number of density cube sets available, 2-4 students per group.
    b. Jigsaw grouping used to create random groups mixing background/ability. Jigsaw accomplished by handing out numbers (1-4) and then asking students to create a group with one of each number.
2. **Provide materials**
    a. Each group received a set of density cubes. Cubes include wood, acrylic, aluminum, and copper.
    b. Cubes are labeled with their identities written on tape.
3. **Provide Students with an activity**
    a. Ask students to place blocks in order of warmest to coldest, and record the order on their worksheet. ***(3 minutes)***

b. Worksheet is provided to guide student thinking and ensure they know the procedure.

Explain

1. Have students explain to the class their reasoning behind why they ranked certain cubes as being warmer or colder than others.
2. Have them fill out a "claim, evidence, reasoning" template for why they think some of the density cubes are warmer or colder than others.
    - Students are provided with a template to help them organize their writing. They may choose to use drawings to assist with their explanations.

Elaboration

1. Have students examine the table of properties on page 2 of the student worksheet.
2. Ask students to discuss with their groups which, if any, of these properties might correlate with their ranking of the density cubes.
    a. Definitions of each property provided as well as the units in symbols as well as full words. Sufficient time provided for students to consider table and look up any words they do not understand.
3. Show students a video explaining specific heat misconceptions. (Closed captions provided for video).
    a. **Video link**: https://www.youtube.com/watch?v=hNGJ0WHXMyE

IV. Plan for Individual Differences:

While ELL accommodations are listed within throughout the lesson plan, there are several pieces of the overall lesson which are planned with differentiated learning in mind.

- The hands-on inquiry lesson engages all students, and the differences observed between the temperature sensation while touching the objects vs. the temperature recorded by the gun should be sufficient to instigate a learning experience based on cognitive dissonance, regardless of whether a student understands the properties given in the chart (specific heat, thermal conductivity, and density).
- Definitions are provided for all the science terms, and sufficient time is provided for students to do personal research on the terms during the inquiry

lesson in case they have questions, need to translate, or need alternative explanations.

- Questions and procedures are on the students' handouts as well as on the slides in order to ensure everyone understands the procedure; those with 504 plans who may become distracted or need refocusing will have resources to get them back on track with the lesson.
- ELL students and students with IEPs can take advantage of an alternative exit slip assignment, better suited to their personal capabilities and their individualized education goals.
- This lesson plan accommodates students who are audio learners (all instructions and questions are read aloud) as well as visual learners (all instructions and questions are shown on the board, and they will also benefit from the inclusion of the video in the Elaboration phase) and kinesthetic learners (who will be able to touch the density blocks and take temperature readings themselves with the infrared thermometer).

V. Evaluation:

Students will complete an "exit slip" activity that acts as a formative assessment for the lesson. **Students will choose one option for displaying their mastery of the content:**

Option 1: Student will develop a procedure for an experiment which explores specific heat and perceived temperature. Procedure should be relatively detailed (but different from the experiment today), include the materials needed, and some table in which to record data or some guiding questions. *(Extension option: Student also creates a statement to explain the concept to another student).*

Option 2: Students will write a short essay (no more than one page) explaining the role of specific heat and/or thermal conductivity in the perception of temperature, and comparing that to the thermal energy of a substance. The essay should display good scientific writing skills, and involve claim, evidence, and reasoning. (*Extension option: student may do independent research and select an article or scholarly source supporting their claim*).

ELL/EIP Option: Students will complete an exit slip which guides student responses (option offered only to certain students who need accommodations).

Grading Rubric:

Assessed Item	Score of 1	Score of 2	Score of 3	Score of 4
All Items: Clear explanation of temperature vs. specific heat	Student displays little to no understanding of either concept.	Student displays basic understanding of temperature as a perceived property but cannot differentiate between perceived temperature and measured temperature.	Student displays advanced understanding of temperature as a perceived property and can differentiate between perceived temperature and measured temperature.	Student displays complete understanding of temperature as a perceived property and can differentiate between perceived temperature and measured temperature.
Option 1: Procedure for theoretical exploration / experiment	Procedure is minimal, not step-by-step, or does not clearly reflect the steps needed to take to address the question.	Procedure structure is developing, but does reflect some of the steps needed to take to address the question.	Procedure structure is clear and appropriate, and does reflect most of the steps needed to take to address the question.	Procedure structure is clear and appropriate, and reflects all of the steps needed to take to address the question completely.
Option 1: Detail items (Materials & Data Collection)	Materials and Data Collection (table and/or graph) are missing or do not target the question.	Either Materials or Data Collection (table and/or graph) are present but need to target the question more clearly.	Both Materials or Data Collection (table and/or graph) are present and target the question sufficiently.	Both Materials or Data Collection (table and/or graph) are present and target the question clearly and effectively..
Option 2: Essay explaining / describing the topic	Essay format is not appropriate to grade-level work (incomplete sentences, unfinished thoughts) and/or does not address the topic.	Essay format is developing, but does not clearly provide scientific writing structure.	Essay format is developing, and there is a developing attempt at scientific writing structure that still has some room for improvement.	Essay format is at grade-level, and scientific writing is clearly present, with claims, evidence and reasoning all present.
Option 2: Essay includes a comparison to thermal energy	Thermal energy is not addressed in the essay.	Thermal energy is either incorrectly defined or is not correctly applied to	Thermal energy is correctly defined, but improvement is needed in applying it	Thermal energy is correctly defined, and related to both Temperature and to

		the concepts given.	to the concepts given.	Specific Heat and/or Conductivity.
Option 3: Student uses Claim-Evidence-Reasoning Format	No CER Structure or content is in evidence in response/	CER structure is present, but labeled incorrectly, and does not display writing skills to the student's ability.	CER structure is present, labeled correctly, but does not display writing skills to the student's ability.	CER structure is present, labeled correctly, and writing is at student's ability or shows improvement on earlier work.
Option 3: Student participation in literacy building process	Student does not participate in activity or makes no effort to speak, write, or communicate.	Student participates minimally in speaking, writing, or communicating, or is extremely distracted.	Student participates moderately in speaking, writing or communicating.	Student participates to the best of his or her ability in the speaking, writing and communication phases of the exploration.

VI. Materials:

- Slide Set: https://docs.google.com/presentation/d/1puh6xKlHMp4qzz17iVcpNg54x-mwyIyFsO_TEKcYkY4/edit?usp=sharing
- Video: https://www.youtube.com/watch?v=hNGJ0WHXMyE
- One set of density cubes per group (or any pure materials of different heat capacities)
- One or more Infrared Thermometers (one per group is ideal)
- Handouts with table of properties & guiding questions (one per student)
- Claim-Evidence-Reasoning template (one per student)
- Exit Slip Assignment (one per EL student)

VII. Safety:

- Do not look directly into the infrared thermometer; may cause injury to eyes.

VIII. References:

American Association for the Advancement of Science. (2017). *Energy: Forms, Transformation, Transfer, and Conservation*. Retrieved from http://assessment.aaas.org/misconceptions/NGM016/248

Fries-Gaither, Jennifer. (2009). *Common Misconceptions about Heat and Insulation.* Retrieved from Ohio State University website:

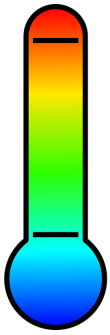
http://beyondpenguins.ehe.osu.edu/issue/keeping-warm/common-misconceptions-about-heat-and-insulation

Florida Department of Education. (2008). *Florida Sunshine State Standards (K-12 science)*. Retrieved from http://www.cpalms.org/homepage/index.aspx

National Science Teachers Association. (2014). *Science and Engineering Practices*. Retrieved from http://ngss.nsta.org/PracticesFull.aspx

Student Worksheet: Temperature Explorations

Pre-Exploration



Scientists often think of certain concepts differently than the general public. As a science student, Attempt to create your own answers to these questions, either here or in your science notebook:

1. What is temperature?

2. How do we measure an object's temperature?

3. What makes an object hot?

4. What makes an object cold?

Exploration

1. You've been given a set of cubes of different materials: Wood, Acrylic, Aluminum and Copper. *Leaving the cubes on the table and only touching them briefly with your finger*, **Rate the cubes from warmest to coolest.**

1 *(Warmest)*	**2**	**3**	**4** *(Coolest)*

Stop here. Be ready to share your thoughts with the class and explain why your group put the blocks in this order. You may choose one person to speak for your group.

2. **T**ake a look at this chart of physical properties of these materials.

Material	**Specific Heat (J/g*K)**	**Thermal Conductivity (W/m-K)**	**Density (g/cm^3)**
Copper	0.39	401	8.96
Aluminum	0.87	205	2.70
Acrylic	1.46 - 2.16	0.20	1.20
Wood (Oak)	2.00	0.16	0.75

Some Useful Definitions:

Specific heat - The amount of heat that must be added or removed from a unit mass of a substance to change its temperature by one Kelvin. *Units are Joules per gram * Kelvin.*

Thermal conductivity - The ability of a material to transfer heat. Given two surfaces on either side of the material with a temperature difference between them, the thermal conductivity is the heat energy transferred per unit time and per unit surface area. *Units are Watts per meter * Kelvin.*

Density - A measure of the mass of a substance per unit volume. *Units are grams per centimeter cubed.*

Now please answer the question:

Do you think any of these properties correlate with how you ranked the blocks? Why?

After answering the question, we'll watch a video together that might give us more insight.

Pre-Exploration

Now that we've watched the video and discussed what's going on, you should have a better understanding of temperature. Consider the following questions:

1. **Has your opinion changed about the initial definition of temperature at the beginning of the lesson? If so, how?** (Make sure to use full sentences and scientific language, including your claim, evidence, and your reasoning/logic).

2. **What role does specific heat and/or thermal conductivity play in how we perceive temperature when we touch an object?**

3. **If temperature cannot be measured (or defined) by what we feel when we touch an object, how do you think temperature might be defined by scientists?** ***Look up "thermal energy" to help you answer this question.***

Claim-Evidence-Reasoning Statement

CLAIM: A statement that answers the original focus question or problem. What conclusion can you make about your original focus question or problem?

EVIDENCE: Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim. What data or observations do you have to support your claim?

REASONING: A justification that links the claim and evidence and includes appropriate and sufficient scientific principles to defend the claim and evidence. How does the data you used for evidence support your claim?

Exit Assignment

Based on your experience today and the answers to the questions above, choose a wrap-up activity, due tomorrow:

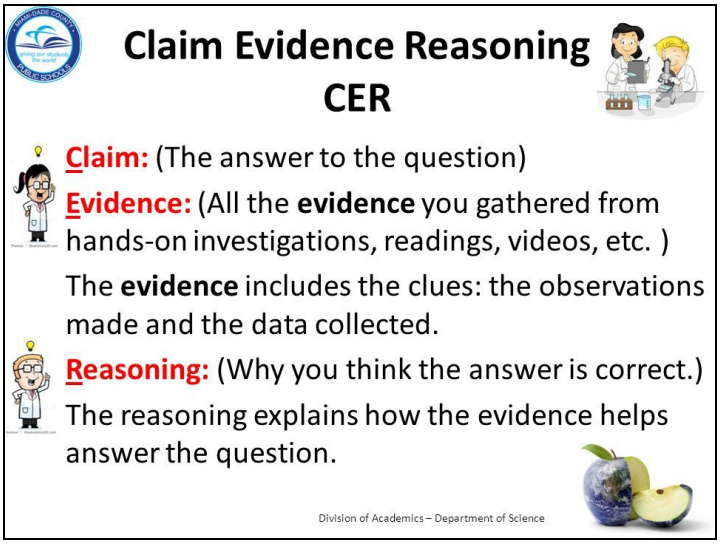
1. **Develop a procedure** for an experiment which explores specific heat and perceived temperature. Your Procedure should be relatively detailed (but different from the experiment today), include the materials needed, and some table in which to record data or some guiding questions.
    a. Bonus Option: Create a statement for after the experiment to explain the concept to another student.

2. **Write a short essay** explaining the role of specific heat and/or thermal conductivity in the perception of temperature, and comparing that to thermal energy of a substance.
    a. Bonus: Do some independent online research and select one or more articles or scholarly sources to support your claim. Cite them based on your citation guidelines in English class.

Exit Assignment Alternative *(given only to certain students who need accommodations)*

Please fill in the blanks below with your claim, evidence and reasoning, based on the experiment we did today. Please try to use full sentences!

You may also draw pictures to help explain.



Claim	I think that temperature is…
Evidence	I think this because in class I observed…
Reasoning	Using my observations, I think my claim is right because…