“Hot” and “Cold”

“Our sensation tells us something, we know that it may not be temperature. So what is the thing we sense?”

Başer, 2006

What’s this lesson all about?

The purpose of this lesson is to help students understand skin or touch cannot determine temperature; it can only tell you how quickly an object conducts energy towards you (feels warm) or away from you (feels cool). The lesson starts by exploring how our bodies interpret heat transfer, and by exploring the feeling of wooden and metal objects. Spoons are suggested for convenience. Students should learn how our bodies can send confusing messages about what is “hot” or “cold”, and how metal “feels colder” than wood, even at the same temperature. It is hoped that, by the end of this lesson, students will understand that:

1. our senses are not sufficient for determining temperature,
2. objects transferring heat to or from our bodies are interpreted by our brains as “cool” or “warm”, and
3. hot and cold is a perception, directly related to energy transfer.

This lesson was designed after learning that many students, especially those in the 15-18 year-old range, believe that objects at room temperature that feel cold have different temperatures, and that some objects are naturally colder than others (Sözbilir, M., 2003). It was also common for students to believe that skin or touch can determine temperature and that perceptions of hot and cold are unrelated to energy transfer. 5 of the 26 questions contained on the TCE (Yeo & Zadnik, 2001) are related to these concepts, as seen below:

• Skin or touch can determine temperature.	16
• Perceptions of hot and cold are unrelated to energy transfer.	10, 18, 21, 22

The structure of this lesson is meant to help teachers facilitate a lesson with their students. Throughout, allow students to explore, to be curious, to ask questions! The lesson will look slightly different for every class, depending on the particular setting. Two physical introductory activities are offered; choose one, or both, depending on your preferences.

This lesson should take place after the TCE Pre-Test and, ideally, after Lesson 1 - Thermal Equilibrium.

Introductory Physical Activity #1 - Hot and Cold... at the Same Temperature?

Materials: Wooden spoons or other wooden materials, metal spoons or other metal materials, thermometers (optional)

- Place wooden and metal spoons/objects around the classroom, making sure to leave plenty of time for them to reach room temperature. *Suggestion - place sets of one wooden and one metal spoon around the classroom to ensure that they aren’t used by several students; students hands will warm the spoons and affect the activity.*
- Have students, individually or in groups, pick up a wooden spoon, and the metal spoon, and describe the feeling of each. They can use this Google Doc to record results, or use paper.
    - Could suggest “Cool, Warm, or Hot”, or have students describe the feeling on a scale from 1-10 where 1 is cold and 10 is hot, or whatever you feel is best for your particular students.

    - Discuss the results in groups, if desired, eventually moving to a whole-class discussion. Focus on the sensation of the objects, and try to have them decide on what the temperature of each spoon might be.
    - This is a great opportunity to relate back to the previous lesson by reminding them that the spoons were sitting in the room for a long time; they should be (and are) at thermal equilibrium when they come in contact with the skin.
- Ask, “can you trust your senses for measuring temperature?”, and have them explain and discuss their answers.
- Have students return to this activity at the end of the lesson to see how their views have changed.

Extension #1: Provide students with thermometers to determine that the wooden and metal spoon are indeed the same temperature. Depending on the thermometer used it may be difficult to determine their temperature; infrared is best but more expensive. This whole step should be unnecessary if students understand from the previous lesson that the spoons are in thermal equilibrium with the room’s air.

Extension #2: Have students choose any other object in the room and measure its temperature. They touch it, describe its feeling in words. They choose a second object they think is colder, measure it, describe its feeling in words.

Introductory Physical Activity #2 - Inner Conflict!

Materials: cold water, warm water, hot water, bowls

- Put some hot water, warm water, and cold water in three separate bowls. Stations work well here.
    - Just use water from a faucet, and be sure that the hot water is not too hot to touch.
- Have students place one hand in the hot water, and one hand in the cold water.
- After a few seconds, have them place them both in the warm water.
- Have students describe the sensations. Ask, “can you trust your senses for measuring temperature?”, and have them explain and discuss their answers.

Teacher Support: *When both hands are placed in the warm water, the hand from the hot water now senses the warm water as cold, and the hand from the cold water now senses the warm water as hot. You can suggest to students that the feeling of hot or cold has much to do with heat being transferred to and from the body.*

Teaching through T-GEM

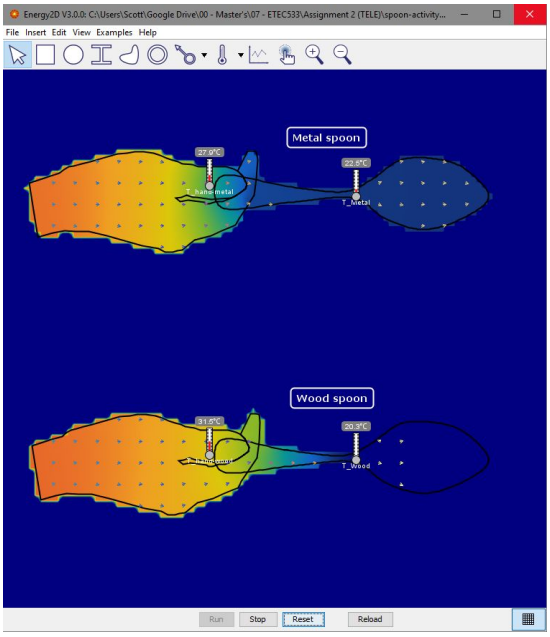
If support is needed for using the Energy2D tool, please see the “Teacher Resources and Tutorials” section of this website.

The rest of this lesson plan, like Lesson 1, is designed for use with the Energy2D simulation tool, and follows a structure guided by T-GEM (Khan, 2011). The procedure involves **T**echnology at each stage and students taking part in the following cycle:

1. Compile Information
2. **G**enerate Relationship(s)
3. **E**valuate Relationship(s)
4. **M**odify Relationship(s)

You can use the following plan as a guide for your own lessons. Please feel free to adapt/modify it for your particular group of students, supplement it with additional inquiry questions, and/or reduce the level of complexity.

Finally, you'll find numerous references to having students compare data, results, predictions, and so on. This can be as informal or formal a process as you feel is best, but I have found it useful to keep track of data-driven lessons using Google Sheets. It allows large sets of data to be compared, and for students to collaborate easily. Feel free to use this template as a sample for how you may want to approach student-student collaboration.

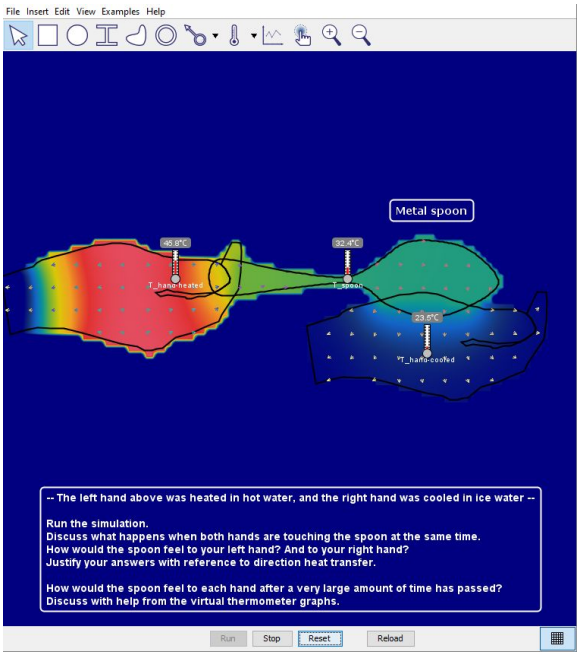
Major Phase of (T-)GEM	Main Teaching Methods	Teacher Guidance Strategies	Computer Simulations
Compile information	Ask students to compile temperature and heat transfer information from a given simulation	Guide students to "hand-activity.e2d" and have them compile information from virtual sensors	Teacher should encourage students to consider interpreting the simulation one variable at a time at first e.g. only the thumb, or the finger, or one of the three thermometers Suggested Examples: hand-activity.e2d
Generate relationship (**G**)	Identify variables for students (Temperature, Time, Direction of Heat Transfer time, Rate of Heat Transfer, Steepness of Graphs)	Limit the scope of variables to explore, suggesting exploration of only one or two variables at once Guide students toward generating a relationship between the temperatures of objects and the **direction** and **rate** of heat transfer	Teacher should encourage students to work through the questions found in the simulation, and to discuss the questions posed Suggested Examples: hand-activity.e2d spoon-activity.e2d Teacher may want to suggest to students to use "View Heat Flux Arrows" and to carefully explore the graphs in each case, with a focus on steepness. 
	Ask students to document their thoughts	Ask students to summarize relationships	Have students write down and discuss what they currently understand about the relationships between the variables, using virtual sensor data as support for arguments.

			Teacher may want to use a Google Sheet like this one as a starting point to help facilitate data sharing, collaboration and comparisons.
	Ask students about relationships between variables	Encourage students to make predictions and discuss variables with each other Potential questions "Will all objects eventually reach the same temperature?" "What would happen if the spoon was a different material?"	Use simulations as a basis for probing questioning Suggested Examples: hand-activity.e2d spoon-activity.e2d conduction-test.e2d (for exploring extra materials)
		Select extreme cases for student investigation Potential questions "Suppose you were stranded outside in -5° C weather and your hands became extremely cold. How would lukewarm water feel?" "Suppose you were stranded in the desert and your hands became extremely hot. How would lukewarm water feel?"	Students could use Simple Conductive Heat Transfer simulation to explore extreme cases by setting extreme variables for materials (massive/tiny thermal conductivity, extremely high/low temperatures, numerous objects in contact, etc) Suggested Examples: simpleheattransfer-custom.e2d
		Ask students to compare results for similar experiments	Teacher could encourage have students log their work, either in a notebook or online using Google Sheets or Google Docs. The latter is recommended to allow sharing, collaboration and robust comparisons and discussions
		Ask students to explain	Teacher could ask students to explain to each other one or more of the relationships they have generated These responses could be recorded using a simple Google Doc
Evaluate the relationship (**E**)	Provide high-level questions which	Ask students one or more of the following: "Is it only objects warmer	Have students attempt to explain their responses with reference to an example from the simulations.

	force students to evaluate their relationships	than us that feel warm? Or colder objects that feel cold?" "How does how brain perceive heat transfer?" "Is it possible to explain how cold or hot something might feel to the touch solely by the steepness of a **hand temperature vs. time** graph?" "What would it feel like to float in water at exactly the temperature of your body?"	These responses and discussion may be recorded in a simple Google Doc.
	Provide an extreme case	Ask students "Which object will conduct energy the fastest?" "How would it feel to touch an object with an extremely high/low thermal conductivity?"	Teacher could direct students to conduction-test.e2d, a case involving more extreme temperatures with a wider variety of materials, to evaluate the relationships they've generated Suggested Examples: conduction-test.e2d
		Ask students "what's different from this and real life?"	Teachers could have students show the simulated hand reaching thermal equilibrium with a spoon, and have them explain if a spoon could cool an entire human body.
	Provide a confirmatory case	Ask students to predict	Teacher should advise students to make predictions before using a the simulation to confirm it
		Do not correct students	Have students work together and continue sharing data to test the scope of any relationships they have generated
Modify the relationship (**M**)		Ask students to revisit their original relationships between variables	Have students reflect in writing or through discussion on how their original ideas did or did not hold up in the face of each new case Students should return to the introductory activity and complete the second section.
		Ask students to summarize relationships	Above all else, encourage students explain why **skin or touch is not enough to determine temperature**, and **how perceived hot or cold is related to heat transfer**.
		Ask students to solve a	Have students complete "Spoon Activity 2".

new case

Suggested Examples:
spoonactivity-2.e2d



Extension 1: Ask students to generate their own example/activity related to this topic for other students using the Energy2D applet's available tools.

Extension 2: Ask students to form groups and come up with a minimum of 3 examples where the concepts covered could be related to real-life scenarios.

Grand Takeaways

1. *Skin or touch is not enough to determine temperature*
2. *Perceived hot or cold is related to heat transfer.*
3. *Our bodies are great at determining heat transfer or relative temperature changes, but not absolute temperatures of objects*

Again, this lesson can be modified to suit your needs, as it covers a large breadth of material. Not every aspect of what's explored above needs to be covered in-depth, but the teacher should ensure that students are questioned throughout the process. The lesson will be more effective if the teacher helps students make connections between the simulations and real-world analogies or situations.

Additional Teacher Guidance

Students should be encouraged to use examples from "real-life" as well as the simulations to support their responses to the questions below.

Question/Prompt	Brief Answer/Explanation
When we touch an object colder than us our brains interpret this as “cold”. When we touch an object hotter than us our brains interpret this as “hot”. Explain this phenomenon by relating it to the **direction of heat transfer**.	*If heat is being transferred away from us we feel cold because we’re losing energy.* *If heat is being transferred towards us we feel warm because we’re gaining energy.*
A wooden spoon and a metal spoon may have the same temperature but they do not “feel” the same temperature. Explain this phenomenon by relating to the How do we explain **rate of heat transfer**.	*The faster heat is transferred away from us (relates to thermal conductivity) the colder it feels. The opposite is also true.* *You may want to guide students back to the graphs found in spoon-activity.e2d and have them compare the steepness of curves.*
Questions within Spoon Activity 1 1) What is the temperature of each spoon at the start? And of each hand? 2) Do both spoons increase in temperature at the same rate? 3) Does the hand change temperature at the same rate for both spoons? 4) What is the direction of heat transfer to the wood and the metal spoons? Is it always the same direction? 5) Does one spoon conduct heat energy more quickly than the other? 6) Why does one spoon feel colder than the other when they are both at the same temperature?	1) *36° C and 20° C* 2) *No* 3) *No* 4) *From the hand to the spoon. Not always; would be opposite if the spoon was higher temperature than the hand.* 5) *Yes; the metal spoon.*
Questions within Spoon Activity 2 Discuss what happens when both hands are touching the spoon at the same time. How would the spoon feel to your left hand? And to your right hand? Justify your answers with reference to direction heat transfer. How would the spoon feel to each hand after a very large amount of time has passed? Discuss with help from the virtual thermometer graphs.	*Various answers expected.*

The next lesson is Lesson 3 - Cups ‘n’ Convection.

Final Notes

- Please forward any feedback you have on this lesson to scottskanes@gmail.com. I’d love to hear what you liked, what you didn’t, what worked, what didn’t or any modifications you’ve made!
- All Energy2D files (.e2d) must be downloaded and opened in Energy2D before they will work.
- The team behind Energy2D is working on a more web-friendly version of their simulations. At the time of this writing this didn’t exist, so Java was begrudgingly used because of the benefits of the tool.
- Until a mobile-friendly version of the tool exists, students should each (or in groups) have a computer/laptop/tablet that can run the software.