CaSTL Center

Hot or Cold?

NSF Center for Chemical Innovation
Chemistry at the Space Time Limit (CaSTL)
https://www.castl.uci.edu/

Essential Question: How is energy transferred between objects or systems?

Content Standard(s) Addressed:
HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

NGSS Practice Standard(s):
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS3-4)

Disciplinary Core Idea:
PS3.B: Conservation of Energy and Energy Transfer
Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4)

Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4)

PS3.D: Energy in Chemical Processes
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-4)

Cross-Cutting Concept
Systems and System Models
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)

Content Learning Objective:
After students are shown cold milk being poured into a hot cup of coffee, they will create a model of how heat is transferred in the cup. They will investigate changes in heat while mixing two liquids of different temperatures and will calculate the heat content of each liquid. Students will describe these energy changes both mathematically and conceptually.

Cooperative Groups:
Teacher will have already set norms for working in groups:

- Take turns
- Everyone shares
- Look at the speaker
- Actively listen
    - Nodding
    - Asking questions for clarification
- Respect others' thinking
- Think before speaking

(from Ferris, S. (2015, July). Making talk productive. *Science and Children, 52*(9), 67 – 73.)

This is a multiple day lesson.

Funding and Credits:
This project was funded by the National Science Foundation Centers for Chemical Innovation award #1414466 to V. Ara Apkarian, Ph.D. at the University of California, Irvine, Department of Chemistry. This lesson was written by Therese B. Shanahan, Ed.D., University of California, Irvine, School of Education and Cal Teach.

ENGAGE: ***Anchoring phenomena and central question, relating lesson to phenomena found in students' everyday lives or phenomena that are potentially intriguing, students come up with ideas or hypotheses that may help answer the central question, students construct an initial model*** **Estimated time: 20 minutes** **Description of Engage: Teacher will demonstrate pouring cold milk into hot coffee then will ask students to create a model for what is happening to the temperature in the cup. Students will come up with ideas in their small groups to explain their observations and will create a drawing on the molecular level that will attempt to explain what they observed. Model must have: drawing on the molecular level of water and milk, arrows to indicate the energy and the direction of the energy flow within the cup and outside of the cup, labels, and a written explanation that describes what the model is showing.**		
Teacher's Role	**Teacher Questions**	**Students' Role & Answers to Teacher Questions**
Asking questions Developing a model	I am going to show you a demonstration and I want you to watch it without talking to your group. After the demonstration, I	 Students talk in their groups and

	want you to talk to your group to share your ideas about what happened and why it happened. The question we are trying to answer is: **How is energy transferred between objects or systems?** Be sure to label the components in your drawing, especially the energy and the direction of the energy flow. The teacher will walk around the room and probe for understanding. *"Where is the energy in your drawing? How are you displaying that? What is your evidence for the energy flow you drew?"*	share their ideas. They get chart paper and markers and draw what happened and attempt to explain what happened in their groups, using everyone's ideas. Groups put their models aside for later. They will add to these models after the investigation. **"***The energy is in the cup. The coffee is hot so we show that with these arrows and the milk is cold, so we show that with the small arrows. The coffee cools off, so we show that with these arrows."*

EXPLORE: ***Students conduct a set of empirical investigations about the phenomena, investigations provide evidence that might be useful for addressing the central question and for revising the students' model, students make observations***

Estimated time: 30 minutes

Description of Explore: The teacher assembles the materials: two 250 ml beakers (one for hot water, one for cold), two thermometers, a timer and a scale to measure the mass of the water being mixed. Students will take the temperature of the two liquids then will pour the cold liquid into the hot one and record the temperature change over 20 minutes.

Teacher's Role	**Teacher Questions**	**Students' Role & Answers to Teacher Questions**
Asking questions Planning an investigation	The teacher will tell the students that they will conduct an investigation to collect evidence to help explain the phenomenon. The teacher tells students that they will try to determine how much heat	Students need to determine which variables they will measure. Depending on when in the school year the students do this investigation, the teacher may give them more or less support. Students need to decide how much water to mix, how to measure the temperature, how to find the mass of the water

	was transferred by mixing the two liquids. The teacher may model the procedures as well so that the students can see how they will conduct their tests. The students will calculate the quantity of heat transferred based on the heat capacity of the water (4.18 J/g-K), the change in temperature in Kelvin and the mass of the water in grams. The teacher will walk around the room and probe for understanding. Students post their calculations on the white board to make their calculations public so everyone can compare the results. "*What do you notice?*" "*What might be going on here that we can't see?*" "*What do you think causes the change in the temperature?*" *Are there any patterns or trends?"* Teacher monitors students' conversations and answers to questions to plan which groups will report out in	since it is in the beaker, . Students watch the teacher to review the steps of the investigations. Students calculate the heat transferred within the cup. They have to decide what the mass of the water is (do they use the mass of the original water or the combined mass of the two liquids mixed?). The recorder in the group posts the mass of the water and the heat transferred on the white board in the appropriate columns that the teacher has prepared. **"***The temperature of the hot water decreased and the temperature of the cold water increased."* *"Energy is being transferred from one liquid to the other."* *"The hot water molecules bumped into the cold water and transferred some energy in the collision."* *"Everyone seems to be getting the same results. The hot water gets colder and the cold water gets warmer."* Students complete their calculations with data from their investigations.

	the Explain. The teacher selects groups purposefully and decides how to sequence ideas shared to build conceptual understanding.	
EXPLAIN: ***Students identify and analyze the patterns they find, explain the result, and reflect the results in relation to their model*** **Estimated time: 30 minutes** **Description of Explain: Students talk in their groups about the data and the patterns that they observe. They try to explain what happened in the investigation and try to apply their explanations to the phenomenon and their model. Teacher also asks questions related to the central question that arose from the phenomenon.**		
Teacher's Role	**Teacher Questions**	**Students' Role & Answers to Teacher Questions**
Creating an explanation Drawing a conclusion from evidence	Teacher tells students to talk in their groups to be sure everyone has an explanation for the patterns they observed in the investigation. Teacher asks questions and chooses groups to reply based on the monitoring done in the Explore, choosing groups based on misconceptions, then simple answers then more complex, abstract answers. "*What did you find in your activity?*" "*What patterns did you see in the data?*" *"What is the direction of the energy flow?"* Use evidence from your investigation to support your statement.	Students talk in their groups to be sure they all agree on their explanation. "*We found* __________." *"From the data on the white board, it seems that the more mass, the more heat transferred."* *"It seems the hot water transferred energy to the cold water because the cold water got warmer."* *"The milk will get warmer while the coffee will get cooler."*

	"How might what we did in this activity explain the phenomenon what happens to the milk and the coffee when they are mixed?	
EVALUATE: ***Students evaluate their initial model with empirical findings and revise their model*** **Estimated time: 20 minutes** **Description of Evaluate: Students return to their models and revise their models based on their new information from their investigation. They refine their explanations based on their evidence. Teacher encourages students to indicate how the energy is transferred along with the direction of energy flow.**		
Teacher's Role	**Teacher Questions**	**Students' Role & Answers to Teacher Questions**
Developing a model Arguing from evidence Communicating information	Teacher directs students to take out their models and add to their drawing, labels, and explanations based on any new evidence they collected in the investigation. Teacher walks around and monitors student work to assess whether students are changing their ideas and adding to their explanations. Teacher encourages students to explain not only the direction of the energy transfer but also how the energy is transferred.	Students work productively to change or add to their models and explanations.
EXPLORE: ***Students investigate fundamental scientific concepts, ideas, and theories related to the phenomena or model that they cannot access through empirical investigations—through text, the teacher or computer simulations*** **Estimated time: 30 minutes** **Description of Explore: Teacher gives the students the link to Test Tube Games: Bond Breaker Classroom Edition https://testtubegames.com/bondbreaker3.html**		

Students can work independently or with one partner to play the first 4 levels of the game, if they have not already played the game in another lesson. These levels will give the students information about attraction and repulsion of particles. Students could access the game in class or on their own since the game can be accessed by their phones or by their tablets if they are in a one-to-one district. The levels that pertain to this lesson are Levels 31 - 35. The students should write down important information that they think could help them revise their models.

Teacher's Role	Teacher Questions	Students' Role & Answers to Teacher Questions
Planning an investigation Drawing a conclusion from evidence Obtaining information Communicating information	When students have completed the levels of the game related to thermal energy, students share with each other what they learned in the game that they think can help them with their model. Teacher brings them together to ask questions about how heat affects molecules. "*How do you think the hot water molecules behave in the cup?*" "*How do you think the cold milk molecules behave before mixing?*" "*What did you learn about how molecules behave when heat is present?*"	Students tell each other what they learned in the lesson. "*They move fast—they shake and twist and turn.*" "*They move much slower.*" "*They move, vibrate, shake.*"

EVALUATE: ***Students evaluate and revise their model using scientific ideas to which they have been introduced***

Estimated time:

Description of Evaluate: Students return to their models one more time to add more information from the game. Students then visit each other's posters to see what others have done with the intent of adding to their own poster. While they look at the posters of other groups, they carry post it notes with them to ask clarifying questions, agree with the information they see on the posters, disagree with the information they see, or add on to the information. Each group then returns to its poster and reads the post its that were left by other students. The students make one last revision to the model.

Teacher's Role	Teacher Questions	Students' Role & Answers to Teacher Questions
Developing a model Creating an explanation Arguing from evidence Communicating information	Teacher tells students to add information to their poster based on the class discussion. Teacher then gives directions on how students will ask clarifying questions, agree with the information they see on the posters, disagree with the information they see, or add on to the information. Students then visit each other's posters to observe what others have done. They leave feedback on the posters with post it notes.	Students work productively to make more revisions. Students then walk around and leave productive comments on post its as feedback to classmates.
EXTEND/ELABORATE: ***Students construct a consensus model either within a small group or as a whole class, using the strengths of each individual's model, students use the consensus model to predict or explain other related phenomena, students determine strengths and limitations of their model for further revision*** **Estimated Time: 10 minutes** **Description of Extend/Elaborate: Teacher gives students a short reading about thermal energy. The teacher asks them if they agree or disagree based on evidence from their investigation or information from the game. Students decide if their model is sufficient to explain the phenomenon.**		
Teacher's Role	**Teacher Questions**	**Students' Role & Answers to Teacher Questions**
Arguing from evidence Communicating information	Teacher facilitates a whole class discussion. Teacher asks students if their models have enough information to explain the phenomenon. What is their evidence? Teacher then asks students	Students will look at their model and decide if they can explain the phenomenon based on what they put on their posters. They need to support their statements with evidence from their model.

	to write three sentences that explain the patterns of interactions they observed in the phenomenon.	Students should write about: What happens when the two liquids mix? In what direction the energy is moving? How the energy is being transferred?

Tools, Materials, & Resources

Equipment needs:	Items: two 250 ml beakers (one for hot water, one for cold), two thermometers, a timer and a scale to measure the mass of the water being mixed
Safety requirements	Students should be careful as they handle the hot water. They should use some protection as they touch the hot beaker.
Visual aids, Powerpoint slides, handouts.	**TestTube Games: Bond Breaker Classroom Edition** **https://testtubegames.com/bondbreaker3.html** **TestTube Games: Bond Breaker 2.0 (full game)** **http://www.testtubegames.com/bondbreaker.html**

Heat Transfer

Data Table

Find the mass of the liquids only. Do not include the mass of the beaker. Show how you found the mass of the liquids.

Record the temperature of the liquids in both beakers before mixing.

Find the change in temperature in the cup after mixing the liquids. What is the change in temperature at the end of 20 minutes?

	Mass of lquid (grams)	Starting Temperature (Kelvin)	Change in Temperature (Kelvin)
Hot water			
Cold water			

What patterns do you notice?

Calculate the heat transferred. Show your work.

Specific heat of water = $\dfrac{\text{quantity of heat transferred}}{\text{Grams of water x temperature change in Kelvin}}$

Thermal Energy

Brown, T., LeMay, H. E., & Bursten, B. (1997). Chemistry: The central science. (7th ed.) Upper Saddle River, NJ: Prentice Hall.

One of our goals in chemistry is to relate the energy changes that we see in our macroscopic world to the kinetic or potential energy of systems at the atomic or molecular level. For example, many substances, such as fuels, release energy when they react. This *chemical energy* is due to potential energy stored in arrangements of atoms of the substance. Likewise, we will see that the energy an object possesses because of its temperature (its *thermal energy*) is associated with the kinetic energy of the molecules in the object. Heat is the transfer of thermal energy from a hotter object (whose molecules have a larger average kinetic energy) to a colder object (whose molecules have a smaller average kinetic energy).