Project ASSESS (2016-18) – sponsored by
KY Dept. of Education (KDE) MSP Program

NOTE: All materials are those of the project team and do not represent KDE endorsement.

UNIVERSITY OF LOUISVILLE
CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

PIMSER
Partnership Institute for Math & Science Education Reform

Classroom Embedded Assessment [CEA] Title: Energy Transformation Within a System

a. Targeted Performance Expectation(s)

07-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

b. Learning Goal(s)

1. Demonstrate that energy is transferred out of hotter regions into colder
2. Develop a model and describe the phenomenon of heat transfer
3. Use the model to explain the process of vaporization.
    - (Thermal Energy added to a system increases the kinetic energy level of the particles of water.)
4. Predict the changes within the system based on the transfer of energy from hot to cold.
5. Support a claim with evidence that energy is transferred out of hotter regions into colder ones.

c. Instructional Context

a. This CEA was administered in the middle of the unit to determine whether students could use a model to make predictions and support a claim using evidence.

b. Lesson Summary

- Students have modeled that higher temperature means faster motion (kinetic energy) of particles. For core of the model, see Tretter & McFadden, (2018). People as particles: Modeling structure and properties of matter with fifth graders. *Science and Children*, *56*(4), 67-73. Add to this model concepts of heat energy = faster-moving particles.
- Students have used the model to show transfer of thermal energy from hotter to colder regions (e.g. half the class modeling 'hot' with lots of motion, other half of room modeling 'cold' with little motion. Then 'remove the hypothetical wall' between them, and the fast-moving students transfer energy to slower-moving ones.
- Students have modeled conduction (e.g. flame of candle touching a metal bar) and convection (e.g. hot air in room transferring to cold refrigerator). These are highlighted as a couple of important ways that thermal energy is transferred from hot to cold.
- Instruction on other types of modeling for thermal transfer, including use of arrows to show heat transfer, or drawing of particle-level perspectives including some way to illustrate speed of vibration (kinetic energy)
- Prior instruction on making a claim and supporting with evidence.

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d. Student Task/Prompt– *see end of document for copy of handouts distributed to students*

- ***See Student Task Sheets at end***

a. Stove with can will be set up in room. Aluminum soda can has a small amount of water in it. The stove is turned on and students are asked to:
   i. Model how heat is moving using 'arrow model'
   ii. Describe the heat transfers taking place
   iii. Model at particle level two the two components of the system inside the can (air, water)
   iv. Identify and model the change in state of the water in the can
   v. Predict what will happen if the boiling water is turned over in a pan of ice water
b. Provide evidence to support a claim that "Energy Moves from a higher temperature to a lower temperature."

NOTE1: Can show a 55-gallon drum being crushed by the same principle of atmospheric pressure differential after heating, closing it off, and putting into ice-water. See "55 gallon steel drum can crush using atmospheric pressure" at
https://www.youtube.com/watch?v=JsoE4F2Pb20 or https://www.youtube.com/watch?v=Uy-SN5j1ogk

NOTE 2: Can show a solid steel train tanker car being crushed by atmospheric pressure as well – myth busters. Instead of heating then cooling to create low pressure inside, they hooked up a vacuum pump to pump out most of the air. See "Myth Busters Impossible Tank Car Implosion" at
https://www.youtube.com/watch?v=JsoE4F2Pb20

SEP= developing and using models; DCI= Energy is transferred out of hotter regions to colder ones CCC= Systems and System Models

e. Success Criteria

Series of Criteria:
1. Did the student show the correct movement of heat from hotter to colder?
2. Did the student identify heat transfers from stove → can → water?
3. Did the students properly model (using the given key) the particle-level view of the system inside the can (air & water)?

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4. Did the student articulate how kinetic energy of water particles continues to go up as heat is added, until the particles leave the liquid and go into gas state (evaporate)?
5. Did the model show evaporation and association with thermal energy?
6. Did prediction include that the cold water will remove energy from the system (can), and that thus the KE of the water/air inside will go down, resulting in the water recondensing and leaving behind a partial vacuum since no air can get in to replace the water vapor becoming liquid.
7. Did the student accurately support the claim that "energy moves from a higher temperature to a lower temperature" using the evidence from the model.

Exemplary Response

- SEE SAMPLE EXEMPLARY RESPONSE AFTER THE STUDENT PAGES AT END

f. Next Instructional Steps

- I Provide students more time to work on modeling skills and show why modeling is important to their everyday life
- Provide more practice using evidence to support a claim.
- Have student model and then use the model to explain other thermal energy transformation phenomena, such as:
    - Leaving frozen peas out on counter
    - Opening door of warm house on cold winter day

g. Student Work Samples

None

h. Reflection and Revision

Shifted this CEA to have more emphasis on particle-level modeling so that students think about kinetic energy of particles (air, water) and how that changes as thermal energy is added or subtracted from a system.

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Energy Transformation in a System

1. Using the image to the right, <u>draw arrows</u> (*use an 'arrow model'*) to show how the thermal energy would move between the cold soda can and the hot stove.

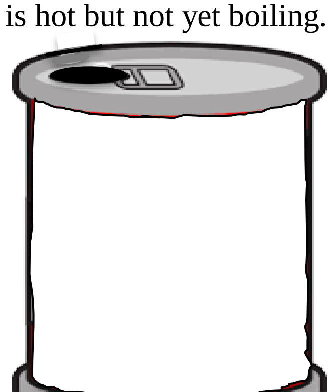
Liquid water in metal can

Stove

2. Identify and describe the heat transfers taking place in the above image, beginning with "heat from stove"….and ending with "heat to water" (*hint: there is one other object between stove and water to account for*).

3. Consider the <u>inside of the can</u> – the water and air that it started with – as your system. Provide a particle-level model of the 2 components of your system (air, water) BEFORE the stove was turned on …..and after the water is hot but not yet boiling.

Before turned on



Water hot but not boiling

Key:
O = water particle
☐ = air particle

Put your pencil down, and pick up a purple pen. As we discuss together whole-class, make changes in your model as needed to show your thinking.

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4. What process is occurring as the state of the water changes due to the heat of the stove? Start by describing the kinetic energy of the water particles, then what happens as heat is continually added.

*The kinetic energy of the water particles*____

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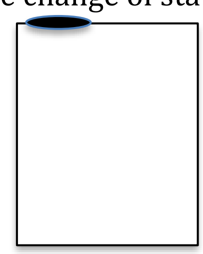
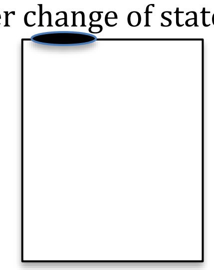
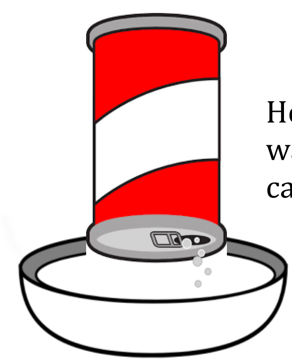
5. Provide a model to show how the process above will change the water and its state. Include in your model a label describing <u>change in thermal energy</u> and the resultant <u>change in the kinetic energy</u> (motion of the particles) of the water.

Before change of state:	After change of state:
can 	can 

6. Predict what will happen if the hot can were turned upside down into a cold dish of water? You can model the movements of energy that could happen or describe the movements.



Hot evaporated water in metal can

Dish of cold water

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Put your pencil down, and pick up a purple pen. After the demonstrations, use the purple pen to modify your prediction to show how energy moved in the system.

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7. Based on the demonstrations, explain what you observed. In your explanation make sure to provide evidence that supports the claim **"Thermal Energy moves from a higher temperature to a lower temperature."**

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Energy Transformation in a System

EXEMPLARY RESPONSE

1. Using the image to the right, draw arrows (*use an 'arrow model'*) to show how the thermal energy would move between the cold soda can and the hot stove.

Yellow arrows show thermal energy flowing from stove to can

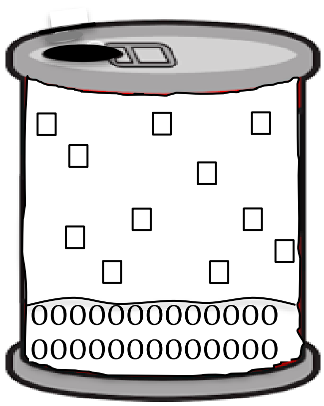
Liquid water in metal can

Stove

2. Identify and describe the heat transfers taking place in the above image, beginning with "heat from stove"….and ending with "heat to water" (*hint: there is one other object between stove and water to account for*).

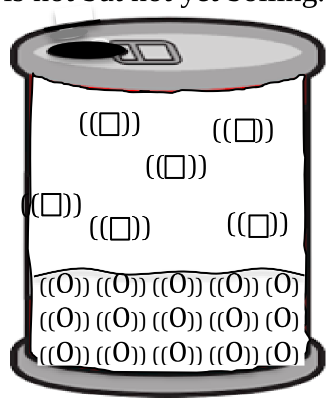
*Heat from stove is transferring to the bottom metal of the can. The bottom metal of the can transfers heat to the water inside. Some of the heat on the bottom of the can transfers up the sides of the metal can to make them hot too, and the hot sides transfer heat to the air inside.*

3. Consider the inside of the can – the water and air that it started with – as your system. Provide a particle-level model of the 2 components of your system (air, water) BEFORE the stove was turned on …..and after the water is hot but not yet boiling.



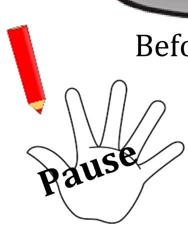
Before turned on

NOTE: Wiggly lines to right indicate water vibrating more, and water has expanded upward. Air particles more spread out too – some escaped out the hole



Water hot but not boiling

Key:
O = water particle
□ = air particle



Put your pencil down, and pick up a purple pen. As we discuss together whole-class, make changes in your model as needed to show your thinking.

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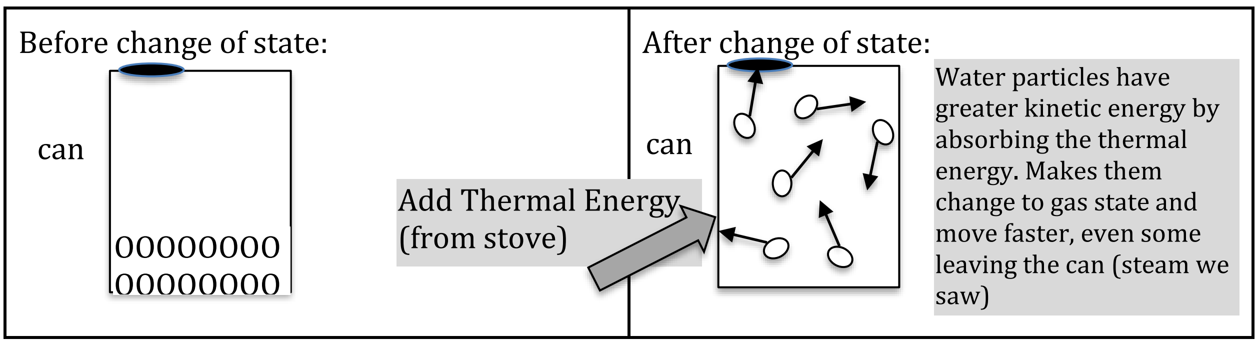
EXEMPLARY RESPONSE

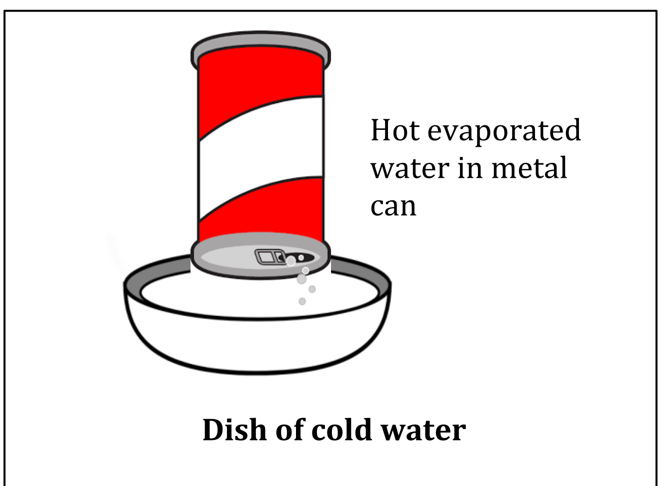
4. What process is occurring as the state of the water changes due to the heat of the stove? Start by describing the kinetic energy of the water particles, then what happens as heat is continually added.

The kinetic energy of the water particles ***is increasing as heat from the stove is transferred to the water. As enough heat is added, this kinetic energy is enough for individual water particles to escape from the rest of the water and go into vapor state. That water has evaporated.***

5. Provide a model to show how the process above will change the water and its state. Include in your model a label describing change in thermal energy and the resultant change in the kinetic energy (motion of the particles) of the water.



6. Predict what will happen if the hot can were turned upside down into a cold dish of water? You can model the movements of energy that could happen or describe the movements.



Thermal energy will move from inside the can where it is hot to the cold water. This will remove thermal energy from the water vapor, causing the water to recondense to liquid. As it does, there is no air to take the place of those particles since the opening is underwater and air can't get in. That means the air pressure inside goes down, and the outside higher air pressure will crush the can.

Put your pencil down, and pick up a purple pen. After the demonstrations, use the purple pen to modify your prediction to show how energy moved in the system.

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EXEMPLARY RESPONSE

7. Based on the demonstrations, explain what you observed. In your explanation make sure to provide evidence that supports the claim **"Thermal Energy moves from a higher temperature to a lower temperature."**

I observed the can being crushed after it was heated and then turned upside down in cold water. I noticed that the can had cooled down quickly after being put into water because the teacher was able to hold it quickly afterward, but before it was to hot to hold with bare hands. I also noted the evidence that there had been steam coming out of the can before being put in the water, but there was no steam afterward which means the inside of the can lost thermal energy. The thermal energy of the hot can must have moved to the cold water. We didn't measure the temperature of the water, but if we did I expect that we would have gotten evidence of the water gaining thermal energy (getting a little hotter).

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