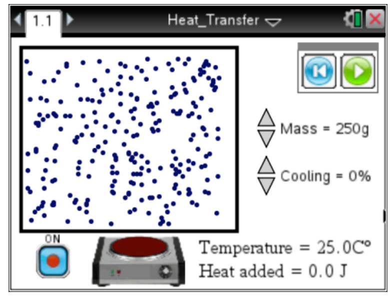
Science Objectives

- Students will explore a simulation of a closed system of particles that can be heated and then opened to allow the heat to escape from it (cooled).
- Students will vary the mass in the system and observe a change in the number of particles.
- Students will heat the system and observe an increase in the activity of the particles. They will note the changes in color and the increase in the number of Joules added to the system.
- As students release energy from the system they will note a drop in temperature and relate this to the cooling rate.
- Students will relate the changes in temperature to transfers through conduction and convection.
- Students will observe the changes in the system as heat is added AND the system is cooled.



Vocabulary

- Temperature
- Cooling
- Convection
- Joule
- Heat
- Conduction
- Radiation
- Calorie
- Energy
- Kinetic Energy
- Specific Heat

About the Lesson

This investigation involves a closed system of particles that can be heated or cooled. Students may increase or decrease the number of particles in the system and observe the motion and color of these particles as the temperature changes. The material in the box is either a gas or a liquid as the temperature changes. The students will explore the ways that heat is added and removed from the system connecting these to conduction, convection, and radiation.

As a result the students will:

- Explore the relationship between temperature and the energy in the system as shown by the color and motion of the particles.
- Relate the increase in temperature with the number of Joules of energy added.
- Connect the drop in temperature with the cooling rate and the motion and color of the particles in the system.
- Apply the concepts of heat transfer (conduction, convection, and radiation) to the changes in the system of particles.

TI-Nspire™ Navigator™

- Send out the *Heat_Transfer.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.
- Quick Poll the class for Formative Assessment.
- Add questions from the student document to the tns file and

Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Heat_Transfer_Student.doc
- Heat_Transfer_Student.pdf

TI-Nspire document

- Heat_Transfer.tns
- Stopwatch or Stopwatch_en.tns from the Science Tools

collect to the Portfolio.

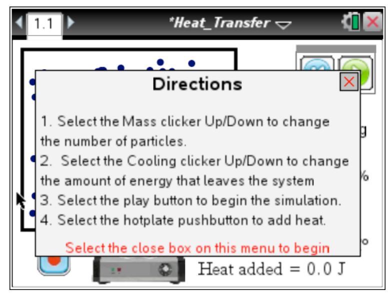
Activity Materials

- Compatible TI Technologies: TI- Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software

Discussion Points and Possible Answers

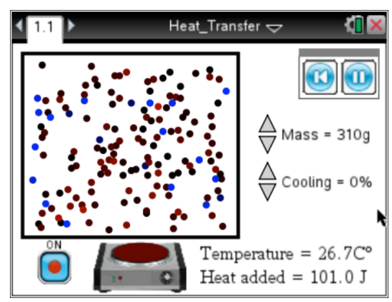
Have students read the background information stated on their activity sheet.

Part 1: Exploring the System



1. After reading the directions for the simulation, students can close the pop-up Directions box by selecting ☒. They can view the directions again by selecting [menu].

> **Tech Tip:** To bring up the directions again, students will need to select 🔧 **> Bring the Heat > Directions**. Note that in some cases, a student may need to back-out to the main Tools Menu 🔧 to see the desired menu option.



2. Students should start the simulation by selecting the Play button ▶. They can adjust the mass and cooling percentage by selecting the up and down arrows of the sliders.

   To pause the simulation select ⏸. To Reset select ⏮.

Q1. What do you observe in this simulation? Write down your answer and share this with a neighbor and the class as requested.

<u>**Sample Answers**</u>: The particles move around and the temperature goes up if the heater is on. If the cooling rate is set, the temperature drops or slows in its increase if the hot plate is on. As you add heat, the number of Joules increases. You can change the mass so that the number of particles in the box changes. The particles move at different speeds in relation to the temperature.

3. Now students will identify the variables in the simulation. Have them change the settings and run the simulation to explore how each of the variables impacts the system. Remind students to reset the simulation between trials. Take note of the variables and answer the question below.

Q2. Fill in the table below based on your exploration. Check with other students as you try to identify the variables.

Variable	How it changes the system	Range of values

<u>Answers</u>:

Variable	How it changes the system	Range of values
mass	changes the number of particles in the box	10 – 500 grams
cooling rate	lowers the temperature; slows the rate of warming	0 - 99%
heating	adds heat to the system and increases the temperature of the particles	0 – 2086.0 J (on reset)
temperature	the color and speed of the particles	0 – 159.2° C

4. Both the motion and color of the particles are related to the average kinetic energy in the system. Since temperature is a measure of the kinetic energy, students should be able to connect the temperature with the particle characteristics, motion and color. Have them explore the simulation again, focusing on the color and speed of motion of the particles. Students should vary the mass to see how motion is affected.

Q3. Describe how color and speed of the particles are related to the temperature of the system.

<u>Answer</u>: As the temperature increases, the speed of the particles increases. In addition, more particles become red as the system gets hotter.

Part 2: Heating the System

5. Now students will explore the relationship between the amount of heat added to the system and the behavior of the particles. Assign groups or individual students a value for their mass and a length of time to heat their system. Students can use the ***Stopwatch_en.tns*** from the TI Science Tools as a timing device. Have them record them below and run the simulation with their assigned settings. **Note: Their cooling rate should be zero and the hot plate should be ON.**

My starting mass ________________________

My time to heat the system _____________________

Teacher Note: Pick values so at least two students have the same values and pick times that are long enough to get a good observation.

Q4. Describe what happened as you ran the simulation with your settings. Include the initial and final temperature and the number of Joules of energy added.

Answer: Answers will vary, but students should note the same starting temperature, 25° C, and mention color and speed changes of the particles.

Q5. Compare your answers with others in the class. Find other students that used the same settings as you. Then, compare your findings with students that used more or less mass than you. Summarize your findings.

Answer: Answers will vary, but students with the same settings should have similar results and students should note that those with different amounts of mass but the same time intervals will have the same amount of heat added, but different ending temperatures.

6. Students should be able to determine the specific heat of the substance in the simulation using the data they collected. Specific heat is the amount of energy needed to change one gram of a substance one degree Celsius.

Q6. How would you calculate the specific heat using the data you collected?

Answer: Take the heat added and divide it by both the change in temperature and the mass to get Joules/degree/gram.

Q7. What mechanism(s) do you think are responsible for the heat transfer that caused the temperature to increase?

Answer: Conduction – the hot plate in contact with the box. Convection – the motion of the particles in the box.

Part 3: Cooling the System

7. Now students will explore the cooling rate for the system. To cool the system, they will open the system so that heat is allowed to escape by setting a cooling rate. Assign groups or individual students a cooling rate, and have them use 200 grams as their starting mass. Remind students to make sure their hot plate is off. Have them record their rate below.

My cooling rate ___________________________

Teacher Note: Try to cover the 10 to 90% range of cooling and give at least two students the same rate.

Q8. Describe what you observe as your particles cool. Note the time it takes to stop cooling and the temperature at which it stops. Also discuss the movement and color of the particles.

Answer: The particles slow down and then turn blue almost stopping as the temperature approaches 0.0° C.

Q9. Compare your results with the class. What pattern do you see?

Answer: The rate of cooling determined the time it took to cool to the same temperature, 0.0° C.

8. Now have students keep their cooling rate constant and repeat the simulation with first a larger and then a smaller mass.

Q10. What can you say about the amount of material you have to cool as it relates to the time it takes to cool completely?

Answer: The greater the mass, the longer it takes to completely cool if the same rate of cooling is used.

Q11. What mechanism could account for this cooling?

Answer: Radiation – emission of infrared radiation, conduction – such as contact with a heat sink, convection – interaction with other particles in such a ways as to not lose any mass.

Part 4: Cooling and Heating the System – Optional Extension

9. The system can be set up to heat and cool at the same time. Some possible questions to explore:

- Could you have a cooling rate that cancels the input of heat from the hot plate so that the temperature stays the same?
- Could you heat the system to a higher temperature and then turn off the hot plate and then start cooling?

Wrap Up

When students are finished with the activity, collect .tns files using TI-Nspire Navigator or Connect-to-Class. If you used Quick Poll or if you added Questions into the tns file you can save grades to the Portfolio. Discuss the students answers to questions using the Review and look at individual files as a class.