Quarrybrook
EXPERIENTIAL EDUCATION CENTER

Program Title: **Trapping the Heat**

Audience: 6th-8th grade students

Program Theme: Heat Exchange—the transfer of thermal energy—is happening continually all around us, whether we are inside or outdoors.

Program Goals: We will work to understand the dynamics of heat transfer through an interactive simulation on the motion of molecules and direct experiences with fire. Students will search for examples of heat transfer taking place in Nature through explorations along the hiking trails. Students will demonstrate their understanding by conducting a hands-on experiment investigating the effects of conduction and air pressure. Students will also examine the visible geothermal system used to heat and cool Quarrybrook's building, with the goal of gaining a practical understanding of how heat exchange works at an industrial level.

Next Generation/Common Core Connections:

Topic: MS-PS3 Energy

Dimensions: Energy and Matter

Objectives:

- **What are the objectives?** Students will understand that heat exchange is the transfer of thermal energy, and that it is happening continually all around us in both man-made and natural settings. Students will make inferences to other possible scenarios of heat transfer in various settings. Students will be able to identify five different natural examples of heat exchange. Students will test their understanding of molecule motion by conducting a temperature-pressure experiment.
- **How will they be measured?** Students will be able to explain the transfer of heat, as seen in action around the campfire and in the woods. Students will compare their predictions with their observations during the air pressure experiment.

Program Outline:

Activity 1: MOLECULE MOTION DEMO (15 min.) – What are molecules? What causes them to move? HEAT! We will work together to kinesthetically demonstrate how temperature affects the motion of molecules. Students will each take on the role of a gas molecule. First, all molecules will group together in a cluster, within a larger area outlined by orange cones. Students will be asked to move around and wiggle without moving their feet. Next, students will be asked to walk around slowly in their contained area, taking small steps. For the last round, students will be asked to run around and move fast in their contained space. If molecules reach the cones they must bounce back inside. After each round, we'll

discuss what temperature the molecules were exposed to (cold, warm, hot) and why each reaction occurred. As air is warmed, the heat energy causes the gas molecules to move faster and farther apart. The same number of air molecules either occupy a larger space, or the same-sized space with increased air pressure. We'll refer back to this physical demo of the energy of motion (kinetic energy) of the gas molecules in cold/hot conditions throughout the field class.

Teachers and chaperones will be helpful in encouraging students to follow the requested movement of each round and to stay in bounds. Adults are encouraged to participate in the demonstration too!

Activity 2: WARMING UP TO HEAT EXCHANGE (30 min.) – This activity is designed to help students gain a visual reference and direct understanding of heat exchange through radiation, conduction, and convection. Students will first gather around a campfire pit to become familiar with key vocabulary associated with the heat exchange process. To experience thermal radiation, students will warm their hands by the fire and be asked to describe what they are feeling. Heat transferred from the fire is being absorbed by our hands, expanding the pores of the skin and increasing the blood flow into our fingers, making them easier to move. We will then boil water to demonstrate conduction and convection. Conduction is shown through the heat transfer of the pot absorbing heat from the fire and, since it is metal, passing (conducting) heat to the water to boil it. This shows convection as the buoyant boiling water from the bottom of the pot rises to the top, and the denser cooler water sinks to the bottom to be heated. Why do the air bubbles in boiling water rise? We will also discuss how insulators and conductors are used to manipulate heat exchange, indoors and outdoors.

Students will then participate in a discussion of examples of the vocabulary words found in the campfire environment, in the boiling of the water, and finally, in the roasting of marshmallows—a great example of heat exchange. What is happening to the marshmallows? They show clear signs of heat exchange by changing shape and size due to increased temperature.

Teachers are welcome to contribute classroom-connecting information. Teachers and chaperones will be key in maintaining a safe environment around the campfire, and throughout the marshmallow roasting experience!

Activity 3: "FIND THE HEAT EXCHANGE" FOREST HIKE (30 min.) – Now students will have the opportunity to explore a Quarrybrook trail and think about where and how heat exchange takes place within the natural environment. How do the animals and plants survive the cold (lack of heat) of winter? To survive the winter many species strive to maintain a constant internal temperature. The group will start observations together, discussing examples we can see around us. As we continue to walk, student sub-teams will be asked to look for additional heat transfer examples on their own, then present their findings to the full group.

Heat Exchange Examples:

- Beavers build dams to raise water levels and create heat exchange between the unfrozen bed of the pond and the water under the ice. Deep water maintains its temperature.
- Beavers build lodges partially under the ice level to create a constant temperature in the lodge that is above freezing. The heat exchange is between the water and the air in the lodge (as is the

geothermal system for our building!) and also between the body temperature of the beavers and the air in the lodge.

- Deer and many other active winter animals have air spaces within the hairs of their fur, which trap heat to keep them warm. The heat exchange is between the body heat of the deer and the air spaces within the hairs.
- When frogs and other amphibians cool down over the winter season, there is heat exchange as the body heat of the frog is lost to the air and mud, allowing the frog's body temperature to become the same as its surroundings.
- Bears and other animals that den for the winter use heat exchange while in their shelters. The heat exchange occurs between the body heat of the animal and the insulating action of its shelter, trapping the heat inside.
- Birds use convection to gain altitude by riding the morning thermal air currents.
- When warm air rises, cold air moves into the opened space. This movement of air is wind!

Teachers and chaperones will be helpful in assisting student sub-teams with their observations and assessments. Teachers are encouraged to ask probing questions and even give clues to help spark discovery and meaningful conversation.

Activity 4: AIR PRESSURE EXPERIMENT (30 min.) – We will reflect back on the "Molecule Motion Demo" and remember how temperature affects the motion of gas molecules. First, the instructor will put a candle in a glass jar and light the candle, while a student inflates a balloon. Students will be asked to predict what will happen if we hold the balloon over the flame of the candle. We will slowly place the balloon over the candle and…watch it pop! The students will be asked why they think this happened. The flame burned a very small hole through the rubber, causing the balloon to burst.

Students will then be split into sub-teams, with one adult per team, and asked to conduct their own experiment. This time, each team will pour a small amount of water into a balloon and then inflate it. Students will be asked to predict what will happen if they hold this balloon with water inside it over a flame. Sub-teams will each put a candle in a glass jar and light the candle. Each team will first hold their balloon over their flame for five seconds. The balloon did not pop and the bottom of the balloon is not even warm! Why? Together we'll discuss how water is a great conductor of heat. The water absorbed the heat of the flame through the rubber, preventing the heat from burning a hole in the balloon.

Next, each team will lower their balloon slowly until it rests on the glass jar over the flame. The balloon will extinguish the flame. Teams will be instructed to wait 20 seconds or so after the flame is out, then be asked to pull upwards on the balloon, showing that the glass jar is now stuck to the balloon. Why did this happen? We'll review how hot air expands, while cold air contracts. The balloon acts as a one-way valve, letting expanding hot air out of the jar, but as the air remaining inside cools and contracts after the flame goes out, no air is allowed back in to take the place of the air that was let out. A partial vacuum is created, reducing the air pressure, pulling the balloon into the jar. Together we'll compare their predictions with their observations. Could this knowledge of molecule motion improve our current building heating systems?

Activity 5: GEOTHERMAL ENERGY INVESTIGATION (15 min.) – As time allows, students will see and learn about Quarrybrook's geothermal system. By heat exchange, a geothermal system uses the constant 56-

degree F water from the ground for heat in winter and for cooling in summer, then sends the water back into the earth to return to 56 degrees again. It is a continuous, natural process, with an unlimited supply of clean, renewable energy, with minimal environmental impact.

At Quarrybrook, our two standing column wells are dug 1,000 feet and 1,500 feet below the earth's surface. Groundwater temperature below 150 feet is a constant 56 degrees. The water from the wells is pumped into the Quarrybrook building into an HVAC system. In winter, conduction extracts warmth from the 56-degree water, which is used to heat the building. The water is returned to the earth approximately five degrees cooler than it was when it came in. In summer, the 56-degree water is used to absorb heat out of the building. The water is returned to the earth approximately five degrees warmer than it was when it came in. The water soon returns to its latent heat temperature of 56 degrees underground. Heat transfer, conduction, and insulation are all part of using geothermal energy in our homes and buildings.

Conclusion/Wrap-up: Students will be asked to explain heat exchange in their own words and give several man-made and natural examples. We'll refer to the branch of physics called thermodynamics, which studies the temperature of objects and the flow of heat between objects of different temperatures. Heat Exchange is happening continually all around us, whether we're inside or outdoors! Students will be encouraged to start noticing these continual transfers of thermal energy that will be happening all around them for the rest of their lives—in Nature, in their homes, at school, at their workplaces, and wherever they go!

Successful completion of this program will help support your students' proficiency in NGSS Performance Expectations:

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.