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| **Title** | Heat Transfer Labs |
| **Introduction** | Through the use of inquiry within this multi lab lesson, students will explore, discover, and then demonstrate their understanding of the processes of conduction, convection and radiation. |
| **Curriculum Alignment** | **Grade 6 Science**:  Objective 1.03  Apply safety procedures in the laboratory and in field studies:   * Recognize potential hazards. * Manipulate materials and equipment. * Conduct appropriate procedures.   Objective 1.05  Analyze evidence to:   * Explain observations. * Make inferences and predictions. * Develop the relationship between evidence and explanation.   Objective 1.06  Use mathematics to gather, organize, and present quantitative data resulting from scientific investigations:   * Measurement. * Analysis of data. * Graphing. * Prediction models.   Objective 1.08  Use oral and written language to:   * Communicate findings. * Defend conclusions of scientific investigations.   Objective 6.01  Determine how conduction, convection, and radiation transfer energy.  Objective 6.02  Analyze heat flow through materials or across space from warm objects to cooler objects until both objects are at equilibrium.  Objective 6.04  Evaluate data for qualitative and quantitative relationships associated with energy transfer and/or transformation.  **Grade 6 Mathematics**  Objective 4.03  Conduct experiments involving simple and compound events.  Objective 4.06  Design and conduct experiments or surveys to solve problems; report and analyze results  **Grade 6 Information Skills**  Objective 5.02  Produce media in various formats (print, graphical, audio, video, multimedia) appropriate to audience and purpose. |
| **Learning Outcomes** | 1. Through the completion of six lab activities, recording their observations, analyzing their collected data, and communicating their findings, students will understand the different methods of heat transfer, the differences between them and how each process works (convection, conduction and radiation) 2. Students will demonstrate their understanding of the methods of heat transfer (convection, conduction and radiation) through diagramming and the written explanation of one or more experimental scenarios. |
| **Time Required and Location** | 1-2 class periods. (50 minutes each)  Labs stations can all be set up both days or can be split up three each day |
| **Materials Needed** | (suggested 2 stations for each to allow for smaller groups)   * Lab notebook (1per student)   Exploration:   * Hand boiler * Large clear glass tank or jar * Ice water * Boiling water * Small bulb bottomed test tube (volumetric flask) * Red food coloring * String   Station 1: - Water Cups Lab: (per station)   * 3 Cups * thermometer * Hot water * Ice water * Room temperature water * Food coloring * Method for timing   Station 2: - Light Bulb Lab: (per station)   * Open bulb lamp * 60 watt bulb   Station 3: - Spoon Lab: (per station)   * Large glass beaker * Boiling water * Plastic spoon * Wooden spoon * Silver spoon * Stainless steel spoon * Glass spoon * Ceramic spoon * Cold butter     Station 4: - Ice Melting Blocks   * Black aluminum block * Black foam block * two O-rings * two ice cubes * Infra red thermometer (Teacher only)   Station 5: - I & C Lab: (per station)   * Foil pieces * Cloth pieces * Plastic gloves * Ice cubes   Station 6: - Balloon Lab (per station)  1 liter bottle  balloon  Container of hot water  Container of ice water |
| **Participant Prior Knowledge** | Prior to this lab lesson, students should have a basic understanding of what energy is, the forms of energy, and the concepts of energy transformation and conservation. |
| **Facilitator Preparations** | Prepare the materials for each station. |
| **Activities** | **EXPLORATION:**   1. Set up an underwater convection volcano and have it flowing at front of the class.  * Fill a clear glass one gallon jug with ice cold water * Tie a string around the neck of a small **volumetric flask** * **Fill v-flask with red food coloring and boiling water** * **Lower v-flask to bottom center of ice water jug**  1. Also have a hand boiler / love meter bird in the palm of your hand.  * Place hand boiler in palm of hand and allow it to warm up and boil.  1. Have students observe both for a few minutes, even pass the love meter bird around the class. 2. Have students complete an I Notice / I Wonder chart about the two items.   **ACTIVITIES:**  **Lab activity**: (designed for students to discover and demonstrate radiation, convection and conduction) (set up two of each of the following stations for best student / activity ratio)  **Directions**: Students will proceed to assigned lab stations and will begin the different lab activities, rotating to each station at assigned intervals (approximately 7 minutes at each station.)  **Station 1**: **Water cups**  Fill three cups with water (1 with ice water, 1 with room temperature water and 1 with boiling water). Measure the amount of thermal energy each cup has by using a thermometer and recording each cups temperature. Place three equal sized drops of food coloring into each (make sure the drops are all of equal sized or it will cause an error in your experiment). Begin timing with each cup as color is added. Time how long it takes for each cup to become completely colored. Predict the order in which you think the cups will become fully colored. Record your observations.  Prediction:   |  |  |  |  | | --- | --- | --- | --- | |  | Hot | Room Temp | Cold | | Temperature (~C) |  |  |  | | Time (sec.) |  |  |  |   Observations:  Questions:   * Which cup became colored first? Second? Last? Why? * How / why did the dye end up coloring the water?   **Station 2**: **Light Bulb Lab**  Have an open bulb lamp set up and plugged in with a 60 watt bulb. Turn it on and wait about 1 minute. Have the students hold the palm of their hands about 10 cm from the SIDE of the bulb for about 15 seconds. Record your observations. Remove hand sooner if it gets too warm. Next hold the palm of the hand about 10 cm above the top of the bulb for about 15 seconds. Record your observations.  Observations:  Questions:   * How / why did your hand get warmer as it was held near the bulb? * In which location did your hand feel warmer? Why?   **Station 3**: **Spoon lab**  Set up a large glass beaker half full with boiling water. Label the different spoons by their material (plastic, wood, silver, steel, glass, ceramic, etc.) Place a dab of solid butter equidistant on each spoon handle near the ends furthest from the water. Have students predict what they think will happen to the butter on the spoons when the spoons are all placed in the beaker of boiling water. Record your observations.  Prediction:  Observations:  Questions:   * How is it that the butter is melting when it is not in direct contact with the hot water? * Why isn’t the butter melting at the same rate on all spoons if they are all in the same water? * How / why are the spoons getting hotter?   **Station 4**: **Ice Melting Blocks**  Procedure with answers:  1. Touch both blocks. Which feels warmer? *(The foam block will feel warmer.)*  2. Predict which block will cause ice to melt faster.  3. Place the O-rings on the blocks to prevent water from flowing off. Place an ice  cube on each block.  4. Observe the rates at which the ice cubes melt. Which material is conducting heat  into the ice faster? *(The aluminum block will melt ice much faster than the foam*  *block.)*  5. After a few minutes, remove the ice and water, and touch the blocks again.  Explain what you observe. *(The aluminum block feels even cooler now, and it is*  *cooler. Energy stored as heat inside the block was transferred to the ice when it*  *melted. Now the block has less thermal energy than before.)*  6. Explain why the aluminum block felt different at the beginning of the experiment.  Was it a different temperature? *(The aluminum block felt cool at the beginning for*  *the same reason that it melted the ice faster. It is better at conducting heat away*  *from your hand, and makes your skin feel cool.)*  **Lab Tips**  An infrared thermometer is useful for measuring the surface temperature of each  block. At the beginning of the experiment, they should be the same temperature.  **Procedure:**  1. Touch both blocks. Which feels warmer? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  2. Predict which block will cause ice to melt faster. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  3. Place the O-rings on the blocks to prevent water from flowing off. Place an ice  cube on each block.  4. Observe the rates at which the ice cubes melt. Which material is conducting heat  into the ice faster? *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*  5. After a few minutes, remove the ice and water, and touch the blocks again.  Explain what you observe.  6. Explain why the aluminum block felt different at the beginning of the experiment.  Was it a different temperature?  **Station 5: C & I lab** **2**  Wrap 3 ice cubes each in a foil packet, a plastic glove and a piece of cloth. And keep three ice cube unwrapped. Hold each in your hand for 20 seconds. Compare the sensation of cold that you feel in each case. Make predictions about what effect each material will have on the transfer of heat. Record your observations.  Prediction:  Observations:  Questions:   * Rank them in order from least cold to most cold. * Why did the different packets feel more or less cold to your hand?   **Station 6: Balloon Lab**  Place a balloon over the opening of a 1 liter bottle. Place the bottle into the hot water container for 5 minutes. Record what happens. Remove the bottle from the hot water and immediately place the bottle into the ice water container. Record what happens. Make your observations.  Observations:  Questions:  Where did the air that filled up the balloon come from?  Where did the air go to that was in the balloon when the bottle was put into the ice water?  **CONTENT WRAP-UP**:  After all groups have completed all stations, bring the students back into the whole group and discuss their observations and answers to the questions. At this time, through this discussion, correct terminology and definitions can be imparted to clear up misunderstandings and to clarify the processes they just examined.  **GUIDED PRACTICE:**  After the class has gone over the lab results and the vocabulary, each student should be given the following sheet for guided practice. Teacher can check in with students as they complete the close activity and questions clearing up any misunderstandings. Following the completion of the close activity, have students use their new understandings to write or diagram explanations for how the underwater volcano and hand boiler work.  **The Transfer of Heat**  Convection conduction convection current  Radiation conductor insulator\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  There are three ways that heat can move. Heat is transferred by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. In the process of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ heat is transferred from one particle of matter to another without the actual movement of the matter. A spoon dipped in hot water gets hot because the spoon’s particles are touching the hot water and heat up. If you watch a pot of water on a stove, you will see the water moving. This movement transfers heat within the water. In \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ heat is transferred by the movement of the currents within a fluid. As water is heated, it becomes less dense. An as a less dense fluid will float to the top of a denser one, the hot water rises. The surrounding cooler water flows into its place replacing it. This flow creates a circular motion known as a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ can also transfer heated air. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is the transfer of energy by electromagnetic waves. You can feel the radiation from a fire in a fire-place all the way across the room. Unlike convection, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ does not require matter to transfer thermal energy. All of the sun’s energy that reaches Earth travels through millions of kilometers of empty space. If two objects have different temperatures, \_\_\_\_\_\_\_\_\_\_\_\_\_ will flow from the warmer object to the cooler one. A \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ transfers thermal energy well. An \_\_\_\_\_\_\_\_\_\_\_\_\_\_ does not transfer thermal energy well. A material that conducts heat easily is called a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. Metals, like silver, steel and copper are good \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. A material that does not conduct heat easily is called an \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. Wood, wool, and paper are good \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.   1. What are the three forms of heat transfer? 2. In what direction does heat move? 3. How are conductors and insulators different? 4. How can heat be transferred through empty space? 5. How does the lemonade in a glass become cold when you put ice in it? |
| **Assessment** | Have students explain how, and through what processes, a fire in the fireplace heats up the stone hearth, a person sitting in the chair, and the air near the ceiling? They should be able to use correct vocabulary and processes to describe and/or diagram what is occurring in each instance. |
| **Critical Vocabulary** | Convection – Heat transferred by the movement of the currents within a fluid. As water is heated, it becomes less dense. An as a less dense fluid will float to the top of a denser one, the hot water rises. The surrounding cooler water flows into its place replacing it.    Conduction – Heat transferred from one particle of matter to another without the actual movement of the matter. A spoon dipped in hot water gets hot because the spoon’s particles are touching the hot water and heat up.  Radiation –The transfer of heat by electromagnetic waves. You can feel the radiation from a fire in a fire-place all the way across the room. Unlike convection and conduction, radiation does not require matter to transfer thermal energy. All of the sun’s energy that reaches Earth travels through millions of kilometers of empty space.  Convection current – is the circular flow of gas or liquid, caused by uneven heating of the medium.  Insulator - A material that inhibits, or slows, the transfer of thermal energy. Wood, wool, and paper are good insulators.  Conductor – A material that aids, or helps the transfer of thermal energy. Metals, like silver, steel and copper are good conductors. |
| **Modifications** | * The lab recording sheets can aid in scaffolding with students who aren’t able to free form their observations and tables. * The structured notes templates can be used for students who need some help starting out their writing of predictions and observations. |
| **Alternative Assessments** | * For students who need more structure for assessment there is a multiple choice test attached. * There are lab entry notebook assessments that can be used to show understanding if the multiple choice tests and the more free form assessments do not work for certain students. * Students can use diagramming of one or more of the activities completed to show their understanding of the appropriate concepts. |
| **References** | Heat Transfer **-** <http://www.wisc-online.com/objects/ViewObject.aspx?ID=SCE304> **–** Good definitions, examples and animations that can aid in student understanding.  Modes of heat transfer - <http://www.bluffton.edu/~bergerd/NSC_111/thermo1.html> - More technical definitions.  Heat transfer - <http://earthfortress.com/wp-content/uploads/2009/06/heatrans.jpg> - Good picture, labeling all three modes of heat transfer.  Cooperative Learning - <http://edtech.kennesaw.edu/intech/cooperativelearning.htm> |
| **Supplemental Information** | Assigning or setting up of lab groups or [Cooperative](http://edtech.kennesaw.edu/intech/cooperativelearning.htm) grouping is critical as you need to put students together that can work together and support each other’s learning.  Be sure to review necessary lab safety requirements for working with hot and breakable materials. |
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