Advanced Manufacturing & Materials, Sensors and Space Vehicles

Thermal Insulators

Grade Levels: 5th and 8th

Academic Content Areas: Science, Technology, Engineering, & Mathematics

Topics: Physical Science, Scientific Inquiry, Science & Technology, and Data Analysis & Probability

Recommended area of co-teaching for an AFRL Engineer or Scientist

Main Problem/Essential Question

How can we determine which material will make the best thermal insulator and which tested material is the best thermal insulator?

Summary

Students will explore thermal insulators through a design challenge in which students study and test insulative properties of common materials after which they will conduct data analysis and use their findings to propose a solution for the design challenge. This lesson includes a student designed experiment as well as a structured experiment.

Big Ideas / Focus

Through research and experimentation this lesson will teach students that; Temperature is a measure of thermal energy. Heat transfer is the transmission of thermal energy from a hotter object to a cooler object. Insulation is a material that reduces or prevents the transmission of sound, heat or electricity. Conduction is the transmission of heat or electricity. And a thermal insulator is a material used to reduce the rate of heat transfer.

There are a variety of methods to measure temperature. Some examples of temperature sensors include; liquid thermometers, spring thermometer, Galileo thermometer, thermocouples (often used with multi meters), thermistors (part of a digital thermostat), and infrared thermography (thermal imaging). We rely on thermal sensors for countless reasons throughout our daily life including; refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets. Students will investigate their homes to create a list of 5 thermal sensors they discovered. A class list will be compiled to demonstrate our reliance on this scientific tool and just how prolific and differentiated thermal sensors have become.

Thermal insulators are affected by water. Wetness even in the form of humidity reduces the insulating ability of a material. When a material gets wet, its ability to insulate is decreased

because water molecules displace air molecules and air molecules are much more insulative than water

The design challenge for this lesson is that students are role-playing as engineers working for ILC Dover (also known as ILC), an engineering development and manufacturing company based in Frederica, Delaware. After being approached by NASA, the company wants to develop a new spacesuit for astronauts. The engineering department (the class) now must study materials that can be used to make this suit, students will test potential materials to determine which material/ materials are best for this application and submit a design including any applicable features that may entice NASA to purchase this spacesuit. Students will design their own experiment and test materials using their experimental design and then complete the provided balloon experiment. After which, the class' recorded data will be accumulated and used to conduct mathematical analysis. Use of the mathematical analysis will help the students make well-informed decisions about their research, as any incorrect data will become evident after analysis.

Prerequisite Knowledge

Students need to be able to conduct Internet inquiry as well as be able to design and conduct a simple experiment. Students should be familiar with mathematical concepts of mean, median, mode, range, and outliers (8th grade only).

Students should have a basic understanding of the difference between a conductor and an insulator. If they do not have this prerequisite, refer to appendix A for a class activity to illustrate this concept.

Standards Connections

Content Area: Science

Physical Science Standard

Students demonstrate an understanding of the composition of physical systems and the concepts and principles that describe and predict physical interactions and events in the natural world. This includes demonstrating an understanding of the structure and properties of matter. In addition, it includes understanding the nature, transfer and conservation of energy; motion and the forces affecting motion; and the nature of waves and interactions of matter and energy. Students demonstrate an understanding of the historical perspectives, scientific approaches and emerging scientific issues associated with the physical sciences.

Grade 5 – Benchmark D: Summarize the way changes in temperature can be produced and thermal energy transferred.	1. Define temperature as the measure of thermal energy and describe the way it is measured. 2. Trace how thermal energy can transfer from one object to another by conduction

Scientific Inquiry Standard

Students develop scientific habits of mind as they use the processes if scientific inquiry to ask valid questions and to gather and analyze information. They understand how to develop plans of action to create and evaluate a variety of conclusions. Students are also able to demonstrate the ability to communicate their findings to others.

Grade 5 – Benchmark A: Use appropriate instruments safely to observe, measure and collect data when conducting a scientific	1. Select and safely use the appropriate tools to collect data when conducting investigations and communicating findings to others (e.g. thermometers,

investigation.	timers, balances, spring scales, magnifiers, microscopes and other appropriate tools).
Grade 5 – Benchmark B: Organize and evaluate observations, measurements, and other data to formulate inferences and conclusions.	3. Use evidence and observations to explain and communicate the results of investigations
Grade 5 – Benchmark C: Develop, design and safely conduct scientific investigations and communicate the results.	4. Identify one or two variables in a simple experiment
Grade 8 – Benchmark A: Explain that there are differing sets of procedures for guiding scientific investigations and procedures are determined by the nature of the investigation, safety considerations and appropriate tools.	1. Choose the appropriate tools or instruments and use relevant safety procedures to complete scientific investigations
Grade 8 – Benchmark B: Analyze and interpret data from scientific investigations using appropriate mathematical skills in order to draw valid conclusions.	3. Read, construct and interpret data in various forms produced by self and others in both written and oral form (e.g., tables, charts, maps, graphs, diagrams and symbols). 4. Apply appropriate math skills to interpret quantitative data (e.g., mean, median and mode)

Science and Technology Standard

Students recognize that science and technology are interconnected and that using technology involves assessment of the benefits, risks, and costs. Students should build scientific and technological knowledge, as well as the skill required to design and construct devices. In addition, they should develop the processes to solve problems and understand that problems may be solved in several ways.

Grade 8 – Benchmark B: Design a solution or product taking into account needs and constraints (e.g., cost, time, trade-offs, safety).	4. Evaluate overall effectiveness of a product design or solution

Content Area: Mathematics

Data Analysis and Probability Standard

Students pose questions and collect, organize, represent, interpret and analyze data to answer those questions. Students develop and evaluate inferences, predictions and arguments that are based on data.

Grade 5 – Benchmark E: Collect, organize, display and interpret data for a specific purpose or need.	2. Select and use a graph that is appropriate for the type of data to be displayed; e.g., numerical vs. categorical data, discrete vs. continuous data. 4. Determine appropriate data to be collected to answer questions posed by students or teacher, collect and display data, and clearly communicate findings.

Grade 5 – Benchmark F: Determine and use the range, mean, median and mode to analyze and compare data and explain what each indicates about the data.	6. Determine and use the range, mean, median and mode, and explain what each does and does not indicate about the set of data.
Grade 8 – Benchmark A: Create, interpret and use graphical displays and statistical measures to describe data; e.g., box-and-whisker plots, histograms, scatterplots, measures of center and variability.	1. Use, create and interpret scatterplots and other types of graphs as appropriate.
Grade 8 – Benchmark D: Find, use and interpret measures of center and spread, such as mean and quartiles, and use those measures to compare and draw conclusions about sets of data.	4. Compare two sets of data using measures of center (mean, mode, median) and measures of spread (range, quartiles, interquartile range, percentiles).
Grade 8 – Benchmark F: Construct convincing arguments based on analysis of data and interpretation of graphs.	9 Construct convincing arguments based on analysis of data and interpretation of graphs.

Preparation for activity

Photocopy pre-/post-test (2 copies per student) and lab sheets

Gather supplies for experiments

Arrange for class use of computers and Internet for day two

Review necessary math standards

Review how to design a basic experiment (establish problem, variable, constant, method of experimentation, recording data, etc.)

Critical Vocabulary

Conductor - a material or an object that transmits heat, electricity, light, or sound (ex. copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, tungsten)

Conduction - the transmission of heat or electricity

Heat transfer - the transmission of thermal energy from a hotter object to a cooler object

Insulation - a material that reduces or prevents the transmission of sound, heat or electricity

Insulator - a material that resists the flow of electric current, heat or light (ex. glass, plastic, rubber, air, wood, porcelain, or silicon)

Temperature - a measure of thermal energy

Thermal insulator - a material used to reduce the rate of heat transfer

Timeframe

Day	Time Allotment	Activities
1	50 minutes	Pre test & Pre activity discussion Homework: Temperature Sensors

2	50 minutes	Internet Inquiry Homework: Complete Lab sheet
3	50 minutes	Role Assignment & Students Design an Experiment Homework: Bring in extra supplies needed for experiment.
4	50 minutes	Student Designed Experiment
5	50 minutes	Balloon Experiment
6	50 minutes	Class Discussion & Data Analysis (compile group findings from the balloon experiment)
*	Optional tour or guest speaker	Arrange for a tour or guest speaker from Wright Patterson Air Force Base Propulsion or materials directorate. *Teacher Note: Make sure you provide your tour guide or guest speaker with clear expectations of the visit including talking points and a brief overview of your student's academic level.* The propulsion directorate at WPAFB uses regenerative cooling as a form of thermal insulation on various spacecraft. One example of how regenerative cooling works as a thermal insulator is on hypersonic vehicles where either the liquid fuel or liquid oxygen is run through channels beneath the vehicular skin. The liquid acts as an insulator, as it warms up it is sent back into the engine and burned as a propellant. This form of thermal insulation increases vehicular weight efficiency by using the fuel for dual purposes. There are many different forms of regenerative cooling in use that are continually being researched by aerospace engineers, mechanical engineers, materials scientists, and technicians within the propulsion directorate for different air force mission systems and vehicles. The materials directorate, RX, at WPAFB is continually researching and experimenting with nanoparticles and microfibers for a variety of purposes including thermal, structural, and electrical. Specific needs and applications depend on project specifications.
7	50 minutes	Post test & Post Discussion

Materials & Equipment

Thermometers (4 per group, plus one for the class)

Round Latex Balloons – all the same size (4 per group)

Small rubber bands (i.e. the kind for braces) or twist ties (four per team)

Fine tip permanent marker (1 per group)

Triple-Beam Balance

Graduated cylinder for measuring water

Small funnel

Stop watches or clock

Wood Spoon

Plastic Spoon (not melamine)

Metal Spoon

Large Bowl

Hot water (~ 100°F) Various testing materials such as; part of an old down coat/blanket, flannel, fleece, long johns, jerseys, Mylar blankets, spandex, etc.

Freezer, refrigerator, cooler with ice, or cold, outside environment

Optional: Cardboard box that is cut to serve as a stand for the filled balloons (1 per group)

Optional: Hot plate and pan (for heating water)

Safety & Disposal

Students should be closely monitored with hot water to ensure safe behavior.

Students need to use caution with thermometers, especially if they are glass or contain mercury.

Students should be cautioned to limit their extremities exposure to frigid temperatures.

Pre-Activity Discussion

Discuss how heat/cold play a role in our lives such as: comfort level, temperature at which you want your food cooked (boiling & killing bacteria), fever, etc. Discuss the importance of monitoring temperature: such as making sure milk does not spoil or when to take fever reduction medicine. Elicit student examples of when they monitor temperature (examples may include shorts/pants, oven temperature to cook a pizza, or even vehicular thermostats / thermometers). Explain that students are going to explore how to control temperature in the upcoming lab.

Teacher Instructions

Day 1: Pre-test & Pre-activity Discussion

1. Administer Pre-test (Appendix F)
2. Lead Pre-activity discussion
3. Assign Homework: Each student is to investigate their home and daily life and create a list of 5 temperature sensors they/their family relies on. *(Some examples include*

refrigerators, stoves, ovens, microwaves, heaters in fish tanks, water heaters, fans in electronics, thermometer, thermostat on furnace or air conditioner, electric blankets, etc.)

Day 2: Internet Inquiry

1. Lead class discussion on homework. Compile a class list of temperature sensors elicit why different sensors are important.
2. Handout student Internet Inquiry worksheets, Appendix B, and discuss the worksheet goals as building background knowledge for the upcoming engineering challenge. (If computer and Internet access is limited pair students as necessary.)
3. Homework: Explain that the information students will compile in the Internet inquiry lab is essential to the engineering challenge and therefore any part that is incomplete is homework and due on Day 3.
4. Allow students the remainder of the class to conduct Internet inquiry. Provide individual direction and clarification as needed.

Day 3: Student Designed Experiment

1. Present Engineering Challenge:

   The design challenge for this lesson is that students are role-playing as engineers working for ILC Dover (also known as ILC), an engineering development and manufacturing company based in Frederica, Delaware. After being approached by NASA, the company wants to develop a new spacesuit for astronauts. The engineering department (the class) now must study materials that can be used to make this suit, students will test potential materials to determine which material/ materials are best for this application and submit a design including any applicable features that may entice NASA to purchase this spacesuit. Students will design their own experiment and test materials using their experimental design and then complete the provided balloon experiment.

2. Discuss that the goal of student research will be to test chosen materials for their insulative ability.
3. Place students into small groups of 3 or 4.
4. Hand out Student Designed Experiment worksheet (Appendix C) and briefly discuss the aspects of designing a simple experiment. Have students complete only the table in the worksheet.

   Teacher Note: Differentiation in this lesson may be necessary for students with less developed scientific skills. If this is the case you may want to instead design 1-3 experiments as a class and then allow students to choose which one they will use in Day 4. In this case, use an electronic white board to complete the Student Designed Experiment Worksheet as a class.

5. Allow students the remainder of class time to complete the table. Visit each group and create a list of basic supplies your students will need for Day 4's experiment.

Teacher Note: An alternative is to create a list of supplies you will have available for Day 4 and have students collect the remaining supplies.

6. Approve all student experiments to ensure for a proper and safe experiment.
7. Homework: Bring in extra supplies needed for experiment.

Day 4: Student Designed Experiment

1. Allow students to conduct the experiment they designed in Day 3.
2. Remind students the importance of accurately collecting data. (Use last page of Student Designed Experiment worksheet, Appendix C)
3. Provide individual direction and clarification as needed. Have students answer the remaining worksheet questions.

Day 5: Balloon Experiment

1. Place students into small groups of 3 or 4.
2. Handout Balloon Experiment worksheet (Appendix D) and briefly discuss the experiment.
3. Discuss possible materials available for testing (provide 3). If possible offer at least one of the same materials tested in the student-designed experiment.
4. Have an acclimated thermometer in the frigid environment for students to collect readings from.
5. Allow students to conduct experiment and complete the worksheet.

Day 6: Class Discussion & Data Analysis
(Compile group findings from the balloon experiment)

1. Lead a class discussion on the findings from both experiments.
2. Have students help graph their findings on the electronic white board. Students may use Excel graphing capabilities if the class has already mastered graphing.

   Teacher Note: 5th graders should create line graphs while 8th graders should create scatter plot graphs.

3. Focus on the results of the balloon experiment. Using an electronic white board, have students compile data and calculations:

   Choose the material students believe to be the best thermal insulator:
   a. Determine the mean for different data sets at each time
   b. Determine the median for different data sets at each time
   c. Determine the mode for different data sets at each time
   d. Are there any outliers (8th grade only)

Teacher Note: Depending on available class time and recorded data you may only want to study the data sets for every six minutes instead of three. Another alternative is to assign each group a data set to calculate.

4. Discuss why it is important to do this analysis before presenting experimental findings.
5. Homework (Appendix E): Draw a labeled design including any applicable features that will entice NASA to purchase this space suit design for their astronauts. Remind students to jot down today's class generated data, as it is needed for the homework.

Day 7: Post-Discussion & Post-test

1. Lead Post-Discussion
2. Administer Post-test (Appendix F)

Background Information

How Mylar blankets work: "People lose heat through thermal radiation. All objects radiate infrared energy. The warmer the object, the more energy is radiated, cooling the object. A thermal blanket is more than 80 percent reflective. That means that more than 80 percent of the thermal energy that reaches it is deflected back towards its source. When someone is wrapped in a thermal blanket, his own reflected infrared heat is reflected back towards him, warming him up more quickly", http://www.ehow.com/how-does_5145153_thermal-blanket-work.html.

Instructional Tips

When a near freezing exterior environment is not available, use of half full ice chests at each lab station works well however, the teacher must try and maintain a consistent temperature of all ice chests so that all data sets can be used.

Use of digital thermometers alleviates most data collection errors.

Assignment of Student Roles and Responsibilities:

Students will all assume the same role:

Role Name	***Brief Description***
Engineer	Responsible for performing experimental tests, manipulating equipment safely & properly, recording data, writing results and conclusions.

Student Instructions

Day	**Activities**
1	Participate in Pre test & Pre activity discussion Complete Homework: Temperature Sensors
2	Hand in completed homework Conduct Internet Inquiry Complete Homework: Internet Inquiry Lab sheet
3	Hand in completed homework

	Participate in group design of an experiment Homework: Bring in extra supplies needed for experiment.
4	Conduct Student Designed Experiment Complete Homework: Lab sheet
5	Conduct Balloon Experiment Complete Homework: Lab sheet
6	Class Discussion & Data Analysis (compile group findings from the balloon experiment) Study for Test
7	Participate in Post test & Post Discussion

Formative Assessments

Student's lab sheets can be monitored and graded to ensure individual understanding of lesson concepts.

Lab Pedagogy Rubric

CATEGORY	4	3	2	1
Contributions/ Team Work	Routinely provides useful ideas when participating in the group or classroom discussion. Contributes a lot of effort. A positive member of the team.	Usually provides useful ideas when participating in the group or classroom discussion. A strong group who shows effort! A positive member of the team.	Sometimes provides useful ideas when participating in the group or classroom discussion. A satisfactory group member who does only what is required. A positive member of the team.	Rarely or never provides productive ideas when participating in the group or classroom discussion. A hindrance to team performance.
Focus on the design challenge	Consistently stays focused on the task and what needs to be done. Very motivated in this challenge.	Focuses on the task and what needs to be done most of the time.	Focuses on the task and what needs to be done some of the time. (Other group members may need to urge this individual to stay on-task.)	Rarely focuses on the task and what needs to be done. Lets others do the work.
Scientific Knowledge	Explanations indicate an accurate understanding of scientific principles	Explanations indicate a basic understanding of scientific principles involved in thermal	Explanations indicate an incomplete understanding as to the principles	It is inconclusive that student understands the principles involved in thermal

	involved in thermal insulation.	insulation.	involved in thermal insulation.	insulation, however student still participated.
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Data Collection & Measurement	Data was collected in a careful manner resulting in measurements within the range of acceptability.	Data was collected carelessly however measurements are still within the range of acceptability.	Data not within the range of acceptability however an attempt was made to document findings.	No data was provided.
Preparedness	Brings needed materials to class and is always ready to work.	Almost always brings needed materials to class and is ready to work.	Almost always brings needed materials but sometimes needs to settle down and get to work.	Often forgets needed materials or is rarely ready to get to work.
Work Ethic	Work reflects this student's best efforts.	Work reflects a strong effort from this student.	Work reflects some effort from this student.	Work reflects very little effort on the part of this student.

Post-Activity Discussion

1. Discuss what students learned about thermal insulation.
2. Discuss how students could have improved their initial experiment.
3. Discuss similarities and differences between the two experiments.
4. Discuss how the experiment improved their product design suggestions for ILC Dover spacesuit design.
5. Elicit what the mean, median, and mode (also outliers for 8th grade only) told students about their data collection.
6. Discuss the importance of visual representation of large data sets as a means to organize and communicate findings.

Pre-Test / Post-Test

Separate Pre-Test/ Post-Test for 5th and 8th grade are provided in Appendix F.
Below are the answers for both exams.

5th grade Pre-Test/Post-Test Answers:

1. Name three tools that can measure thermal energy. *Possible answers include: liquid thermometers, digital thermometers, spring thermometers, Galileo thermometers, thermocouples, thermistors, infrared thermograph, and thermostats.*

2. What is a thermal Insulator? *A thermal insulator is something that prevents heat energy from moving from one place to another. A material that does not conduct heat energy well, i.e. has a relatively low thermal conductivity.*
3. Provide an example of an insulator, conductor, and location of a temperature sensor.

   Insulator: Plastics, wood, cork, fiberglass insulation, glass, plastic, rubber, air, wood, porcelain, silicon, Mylar blanket, and some fabrics are good thermal insulators.

   Conductor: metal such as copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, or tungsten.

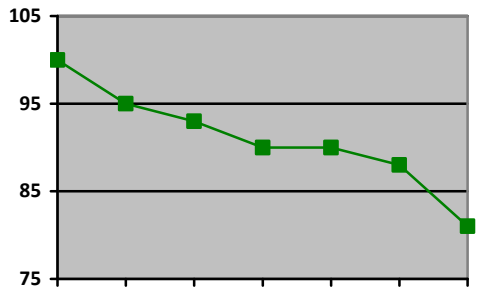
   Temperature Sensor: refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets.
4. What makes one material a better thermal insulator than another?

   The materials ability to insulate this can be accomplished through trapping air or reflecting thermal energy.
5. How does humidity or wetness affect a material's ability to insulate?

   Water is a good conductor of heat energy unlike air. When a material gets wet, its ability to insulate is decreased.
6. What is a conductor?

   A conductor is a material or an object that transmits heat, electricity, light, or sound.
7. Find the mean, median, mode, and range for the following temperatures: 100, 95, 93, 90, 90, 88, and 81.

   Mean: 91
   Median: 90
   Mode: 90
   Range: 19
8. Construct a line graph that represents the following temperature readings: 100, 95, 93, 90, 90, 88, and 81.



9. Name three ways in which you depend on insulation.

   Student answers will vary but may include: outside thermometer, oven thermometer, thermostat, fiberglass insulation for house, earplugs for noise insulation, layers of clothing or clothing to insulate from the elements, etc.

8th grade Pre-Test/Post-Test Answers:

1. Name three tools that can measure thermal energy. *Possible answers include: liquid thermometers, digital thermometers, spring thermometers, Galileo thermometers, thermocouples, thermistors, infrared thermograph, and thermostats.*
2. What is a thermal Insulator? *A thermal insulator is something that prevents heat energy from moving from one place to another. A material that does not conduct heat energy well, i.e. has a relatively low thermal conductivity.*
3. Provide an example of an insulator, conductor, and location of a temperature sensor.

   Insulator: Plastics, wood, cork, fiberglass insulation, glass, plastic, rubber, air, wood, porcelain, silicon, Mylar blanket, and some fabrics are good thermal insulators.

   Conductor: metal such as copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, or tungsten.

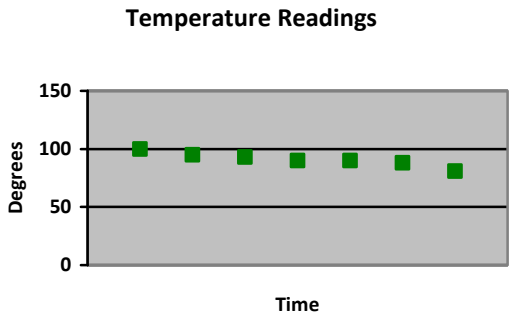
   Temperature Sensor: refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets.
4. What makes one material a better thermal insulator than another?

   The materials ability to trap air, reflect thermal energy, or stop energy from moving from one place to another.
5. How does humidity or wetness affect a material's ability to insulate?

   Water is a good conductor of heat energy unlike air. When a material gets wet, its ability to insulate is decreased.
6. What is a conductor?

   A conductor is a material or an object that transmits heat, electricity, light, or sound.
7. Find the mean, median, mode, and range with and without the outlier for the following temperatures: 100, 95, 93, 90, 90, 88, and 81. Identify the outlier.

With the outlier	***Without the outlier (81)***
Mean: 91	*Mean: 92.67*
Median: 90	*Median: 90*
Mode: 90	*Mode: 90*
Range: 19	*Range: 12*
8. Construct a scatter plot that represents the following temperature readings: 100, 95, 93, 90, 90, 88, and 81 and determine if there is a positive, negative or no correlation. Remember to label the graph and axis.



There is a negative correlation .

9. Name three ways in which you depend on insulation.

   Student answers will vary but may include: outside thermometer, oven thermometer, thermostat, fiberglass insulation for house, earplugs for noise insulation, layers of clothing or clothing to insulate from the elements, etc.

Pre-Test/ Post-Test Rubric

	3 points	2 points	1 point
1. Name three tools that can measure thermal energy.	Student provides three examples of tools that measure thermal energy such as: liquid thermometers, digital thermometers, spring thermometers, Galileo thermometers, thermocouples, thermistors, infrared thermograph, or thermostats.	Student provides two examples of tools that measure thermal energy such as: liquid thermometers, digital thermometers, spring thermometers, Galileo thermometers, thermocouples, thermistors, infrared thermograph, or thermostats.	Student provides one example of a tool that measure thermal energy such as: liquid thermometers, digital thermometers, spring thermometers, Galileo thermometers, thermocouples, thermistors, infrared thermograph, or thermostats.
2. What is a thermal Insulator?	Student states that: a thermal insulator prevents heat energy from moving from one place to another or is a material that does not conduct heat energy well, or has a relatively low thermal conductivity.	Student states that: a thermal insulator helps keep the temperature the same but the answer does not include anything key terms such as energy, low conductivity, or heat movement.	Student provides an example but does not define the term.
3. Provide an example of an insulator, conductor, and location of a temperature sensor.	Student provides a correct answer for each category: insulator, conductor, and temperature sensor. Examples include: Insulator: Plastics, wood, cork, fiberglass insulation, glass, plastic, rubber, air, wood,	Student provides a correct answer for two of the three categories: insulator, conductor, and temperature sensor. Examples include: Insulator: Plastics, wood,	Student provides a correct answer for one of the three categories: insulator, conductor, and temperature sensor. Examples include: Insulator: Plastics, wood,

	porcelain, silicon, Mylar blanket, and some fabrics are good thermal insulators. Conductor: metal such as copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, or tungsten. Temperature Sensor: refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets.	cork, fiberglass insulation, glass, plastic, rubber, air, wood, porcelain, silicon, Mylar blanket, and some fabrics are good thermal insulators. Conductor: metal such as copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, or tungsten. Temperature Sensor: refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets.	cork, fiberglass insulation, glass, plastic, rubber, air, wood, porcelain, silicon, Mylar blanket, and some fabrics are good thermal insulators. Conductor: metal such as copper, aluminum, gold, iron, silver, lead, tin, platinum, nickel, or tungsten. Temperature Sensor: refrigerators, stoves, ovens and microwaves, heaters in fish tanks, water heaters, fans in electronics, personal thermometers, thermostat on furnace or air conditioner, and electric blankets.
4. What makes one material a better thermal insulator than another?	Student states that: The materials ability to trap air OR its ability to reflect thermal energy OR the materials ability to stop energy from moving from one place to another OR its ability to better maintain the initial temperature will make for a better thermal insulator.	Student provides an example of two thermal insulators and shares which one is a better insulator**.**	Student's response attempts to convey an understanding of thermal insulation but no concrete definition or example is provided.
5**.** How does humidity or wetness affect a material's ability to insulate?	Student states that wetness/humidity will decrease the materials ability to insulate and that water is a conductor or less insulative than the air that the water has replaced.	Student states that wetness/humidity will decrease the materials ability to insulate but does not correctly explain how the insulation is decreased.	Student states that wetness/humidity will decrease the materials ability to insulate but does not provide any explanation on how the insulation is decreased.
6. What is a conductor?	Student states that a conductor is a material or an object that transmits heat, electricity, light, or sound.	Student states that a conductor is the opposite of an insulator but does not explain why.	Student provides an example of a conductor but does not provide a definition.
5th Grade Test 7. Find the mean, median,	Student correctly answers all four parts: Mean: 91 Median: 90 Mode: 90	Student correctly answers all three of the four parts: Mean: 91 Median: 90 Mode: 90	Student correctly answers all two of the four parts: Mean: 91 Median: 90 Mode: 90

mode, and range for the given temperatures.	Range: 19	Range: 19	Range: 19
8th Grade Test 7. Find the mean, median, mode, and range with and without the outlier for the given temperatures.	Student correctly identifies all 9 parts of the question. With outlier: Mean: 91 Median: 90 Mode: 90 Range: 19 Without outlier Mean: 92.67 Median: 90 Mode: 90 Range: 12 Outlier: 81	Student correctly identifies all at least 6 parts of the question. With outlier: Mean: 91 Median: 90 Mode: 90 Range: 19 Without outlier Mean: 92.67 Median: 90 Mode: 90 Range: 12 Outlier: 81	Student correctly identifies all at least 4 parts of the question. With outlier: Mean: 91 Median: 90 Mode: 90 Range: 19 Without outlier Mean: 92.67 Median: 90 Mode: 90 Range: 12 Outlier: 81
5th Grade Test 8. Construct a line graph that represents the given temperature readings.	Student constructs an accurate line graph including all 7 points.	Student constructs a line graph that is mostly correct and includes at least 5 points.	Student constructs an incomplete graph OR a graph that is not a line graph OR the line graph consists of at least 3 incorrect OR missing data points.
8th Grade Test 8. Construct a scatter plot that represents the given temperature readings and determine if there is a positive, negative or no correlation. Remember to label the graph and axis.	Student constructs scatter plot graph that includes all 9 of the following categories: 7 Correct data points, labeled axis and graph title.	Student constructs scatter plot graph that includes 7 of the following categories: 7 Correct data points, labeled axis and graph title.	Student constructs scatter plot graph that includes 5 of the following categories: 7 Correct data points, labeled axis and graph title.
9. Name three ways in which you depend on	Student provides three correct examples of how they depend on insulation.	Student provides two correct examples of how they depend on insulation.	Student provides one correct example of how they depend on insulation.

insulation.	Examples include: outside thermometer, oven thermometer, thermostat, fiberglass insulation for house, earplugs for noise insulation, layers of clothing or clothing to insulate from the elements, etc.	Examples include: outside thermometer, oven thermometer, thermostat, fiberglass insulation for house, earplugs for noise insulation, layers of clothing or clothing to insulate from the elements, etc.	Examples include: outside thermometer, oven thermometer, thermostat, fiberglass insulation for house, earplugs for noise insulation, layers of clothing or clothing to insulate from the elements, etc.

Technology Connection

The **ADISC** Model of technology created by ITEL

Integration Model	Application Description
Technology that supports students and teachers in **adjusting, adapting, or augmenting** teaching and learning to meet the needs of individual learners or groups of learners	Electronic White Board
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	Electronic White Board MS Excel
Technology that supports students and teachers in conducting **inquiry**, including the effective use of Internet research methods	Internet Temperature Sensors Mylar blanket
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	Refrigerator/Freezer/Cooler
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	Electronic White Board MS Excel

Interdisciplinary Connection

Biology

Have students research what our normal body temperature is, what hypothermia is, and what causes it (show a short clip of the Titanic movie and relate hypothermia to Jack's death).

Have students research and explain the difference between cold blooded and warm-blooded animals. Do all warm-blooded animals have the same body temperature? Do all humans have the same body temperature – have the entire class take their temperature using an ear thermometer with ear liners and create a graph- determine the mean, median and mode.

Have students research why we sweat, how we sweat, and why this helps cool us down. What makes us sweat when we are nervous? This can lead to many health-related topics including salt intake, understanding the use and misuse of sport drinks, diet, personal hygiene, etc. One resource is http://www.health.howstuffworks.com/sweat2.htm.

Social Studies
Have students research homelessness. Many homeless people use cardboard boxes for shelter. Does this provide any insulation from the cold? How many homeless people are in your community? What are some of the causes of homelessness in your community or in the US? How can we help homeless people? This project can be extended to include a service-learning component where blankets, coats, gloves and other outerwear are collected and donated to a local homeless shelter or at the older grades, this might include having the students interview representatives from a homeless shelter and using their new found knowledge to create a campaign to promote awareness about homelessness in the community. A source of information on homelessness including reasons for homelessness and ways to help is: http://www.homelessresourcesnetwork.org .

History
Have students investigate who Galileo is and what is a thermoscope? Or, Anders Celsius and Gabriel D. Fahrenheit? What countries use the Celsius scale, which countries use the Fahrenheit scale? Link: (http://www.home.comcast.net/~igpl/Temperature.html). *Investigate* global warming including its scientific debut and the first impact this theory has had on our nation and the world? How might it affect us in the future? How do scientists measure the earth's temperature to know that Global Warming is occurring? (http://www.eoearth.org/article/Global_warming)

Investigate the invention of the individual room thermostat that was invented in 1919 by an African –American woman. Link: (http://www.teachervision.fen.com/womens history/printable/19418.html)

English
Students can write lab reflections or develop advertisements or commercials to promote awareness about any of the aforementioned topics, make presentations using Power Point, or develop a website to promote awareness about these topics, etc.

Home Connection
Students will investigate how they rely on and use temperature sensors in their daily lives. This information can be shared with family members to spark more curiosity in additional temperature sensors or other forms of sensors the students might use (ex. light sensors or motion sensors).

Differentiated Instruction
Differentiation in process and product: this lesson may be necessary for students with less developed scientific skills. If this is the case you may want to instead design 1-3 experiments as a class and then allow students to choose which one they will use in day 4. In this case, use an electronic white board to complete the Student Designed Experiment Worksheet as a class.

Differentiation in content: Repeat experiment with wet versus dry materials

Extension
This activity could involve the MIT Second Skin Space Suit.

This activity could involve the Speedo Shark Skin Suit used by swimmers in the Olympics.

This activity can include building and testing a solar cooker.

Career Connection

The propulsion directorate at WPAFB uses regenerative cooling as a form of thermal insulation on various spacecraft. One example of how regenerative cooling works as a thermal insulator is on hypersonic vehicles where either the liquid fuel or liquid oxygen is run through channels beneath the vehicular skin. The liquid acts as an insulator, as it warms up it is sent back into the engine and burned as a propellant. This form of thermal insulation increases vehicular weight efficiency by using the fuel for dual purposes. There are many different forms of regenerative cooling in use that are continually being researched by aerospace engineers, mechanical engineers, materials scientists, and technicians within the propulsion directorate for different air force mission systems and vehicles.

The materials directorate, RX, at WPAFB is continually researching and experimenting with nanoparticles and microfibers for a variety of purposes including thermal, structural, and electrical. Specific needs and applications depend on project specifications.

NASA engineers have designed a liquid cooling system for astronauts as part of their extravehicular mobility unit (the spacesuit they wear outside of the spacecraft). Material engineers and scientists who designed this suit needed to ensure the astronauts safety, mobility and ability to work while in the suit. Their design includes critical features such as temperature regulation through insulative materials (such as Mylar) as well as a, communication device, oxygen, fan, and battery pack. More information can be found at: http://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit_nf.html.

Additional Resources

Resources:	Purpose and Application
http://findarticles.com/p/articles/mi_qa5325/is_200804/ai_n25419583	Hutchinson, Harry, (April, 2008). Beyond the sharkskin suit, Mechanical Engineering Magazine.
http://www.speedo80.com/lzr-racer/development/	Development of the LZR RACER concept (the Speedo Skin Swim Suit).
http://coachpete.wordpress.com/2008/05/02/a-suit-designed-for-olympic-swimmers-speedo-claims-latest-swimsuit-leaves-the-competition-in-its-wake/	"A suit designed of Olympic Swimmers, Speedo Claims Latest Swimsuit Leaves the Competition in Its Wake" by ABC News.
http://www.designnews.com/index.asp?layout=article&articleid=CA6532320	"Speedo's Swimsuit for the Beijing Olympics Is Not A Drag," Design News, June 30, 2008.

http://www.ilcdover.com/About-ILC/

Credits

Winnie Billiel- Contributing Author
Ann Drake- Contributing Author
Dr. Margaret Pinnell - Main Author

Norma Howell - Contributing Author, Editor
Sandra Preiss - Contributing Author, Editor

Teacher Reflections

- Were students focused and on task throughout the lesson? *Insert answer here.*
- If not, what improvements could be made the next time this lesson is used? *Insert answer here.*
- Were the students led too much in the lesson or did they need more guidance? *Insert answer here.*
- Did the students learn what they were supposed to learn? *Insert answer here.*
- How do you know? *Insert answer here.*
- How did students demonstrate that they were actively learning? *Insert answer here.*
- Did you find it necessary to make any adjustments during the lesson? *Insert answer here.*
- What were they? *Insert answer here.*
- Did the materials that the students were using affect classroom behavior or management? *Insert answer here.*
- What were some of the problems students encountered when using the …? *Insert answer here.*
- Are there better items that can be used next time? *Insert answer here.*
- Which ones worked particularly well? *Insert answer here.*

Additional Comments

Appendix A: Conductors & Insulators Demonstration

Materials:

Wood Spoon

Plastic Spoon (not melamine)

Metal Spoon

Large Bowl

Hot Water

Demonstration:

1. Place long handled spoons made of metal, plastic, and wood in a container of hot water for 5-10 minutes.
2. Discuss the term conductor and insulator as defined in this lesson as the spoons sit.
3. Have students hypothesize which material (wood, metal, or plastic) will conduct the most heat and the least heat.
4. Choose 3 class members to come and take readings on the temperature of the spoon using their hand as a temperature sensor.
5. Discuss:
    a. Compare results to student's hypotheses.
    b. Discuss the results (the metal spoon will feel hotter than the plastic and wooden spoons; the wooden and plastic spoons are insulators but the metal spoon is a conductor) and ask students to suggest why saucepans often have wooden or plastic handles (to insulate your hand from the heat).
    c. Metals are not good thermal insulators but wood and plastics are. Metals however, are good electrical conductors are often good thermal conductors.

Appendix B:Thermal Insulators Lesson: Internet Inquiry

Name _____

Directions: Conduct Internet research to help complete the following worksheet. Make sure you understand the information you are collecting including all vocabulary. DO NOT PLAGARIZE!

Definitions:

1. Heat transfer-

2. Conduction-

3. An example of a conductor is: _____.

4. Insulation-

5. Thermal Insulator-

6. An example of an insulator is: _____.

7. Temperature-

Questions:

8. What makes one material a better insulator than another?

9. How does conduction affect the temperature of a non-insulated object?

10. How does humidity or wetness affect a materials ability to insulate?

11. What is the average body temperature of a human?

12. List 4 examples of when you depend on insulation.

Type of Insulation	***Importance***

13. List three tools that can measure temperature. (Hint: think about the homework assignment)

Type of Temperature Sensor	***Basics on how it works***

14. What is thermal energy?

Appendix C: Student Designed Experiment: Thermal Insulators

Name _____

Engineering Design Challenge:

You are an engineer working for ILC Dover. After being approached by NASA, the company wants to develop a new spacesuit for astronauts. The engineering department (the class) now must study materials that can be used to make this suit, test potential materials to determine which material / materials is the best for this application and submit a design including any applicable features that will entice NASA to purchase this spacesuit design for their astronauts. Students will design their own experiment and test materials using their experimental design and then complete an additional teacher provided experiment.

Directions: Complete the table below to help you create an experiment.

Problem:	
Hypothesis	
What are you testing?	
Experimental design	

Control	
Variable(s)	
How is data collected?	
Tools Needed	
Materials Needed	
How much data will you collect? (How many readings over how much time?)	
What will your data tell you?	
What conclusion can you draw from your data?	

Experimental Findings:

Draw and label a picture of your experiment

What types of thermal insulators did you study?

What happened to the thermal energy you were trying to insulate?
(Hint: thermal energy = heat)

What did you learn about your variables?

What will be your materials suggestion for ILC Dover?

Appendix D

Name _____

Balloon Experiment: Thermal Insulators

Engineering Design Challenge:

You are an engineer working for ILC Dover. After being approached by NASA, the company wants to develop a new spacesuit for astronauts. The engineering department (the class) now must study materials that can be used to make this suit, test potential materials to determine which material / materials is the best for this application and submit a design including any applicable features that will entice NASA to purchase this spacesuit design for their astronauts. Students will design their own experiment and test materials using their experimental design and then complete an additional teacher provided experiment.

Materials:

4 balloons

4 small rubber bands

Fine tip permanent marker

Triple-Beam Balance

Graduated cylinder for measuring water

Small funnel

Cardboard box that is cut to serve as a stand for the filled balloons (optional)

3 different samples of insulative materials

Clock or stop watch

Directions:

✓ the boxes as you complete the steps

☐ Use graduated cylinder to fill four balloons with the same amount of hot water (~100°F).

☐ Secure the top of the balloon with a rubber band.

☐ Number each balloon 1-4

☐ Weigh the balloons to make sure that each is filled with the same volume of water.

☐ Record Balloons Individual Weight: _____

☐ Remove rubber band from the top of each balloon, and place the thermometers in the balloons, use the rubber band to secure the top of the balloons around the thermometers.

☐ Wrap three of the four balloons in the different materials and record variables:

Balloon Number	***Variable being tested***

Place the balloons in frigid environment and record data:

Time	***Environmental Temperature***	***Balloon 1 Temp.***	***Balloon 2 Temp.***	***Balloon 3 Temp.***	***Balloon 4 Temp.***
0 minutes					
3 minutes					
6 minutes					
9 minutes					
12 minutes					
15 minutes					
18 minutes					
21 minutes					
24 minutes					
27 minutes					
30 minutes					

Graph your findings (use additional paper if necessary):

What conclusions can you draw from your experiment?

What will be your materials suggestion for ILC Dover?

Appendix E:Design Proposal: Thermal Insulators

Name _____

Engineering Design Challenge:

You are an engineer working for ILC Dover. After being approached by NASA, the company wants to develop a new spacesuit for astronauts. The engineering department (the class) now must study materials that can be used to make this suit, test potential materials to determine which material / materials is the best for this application and submit a design including any applicable features that will entice NASA to purchase this spacesuit design for their astronauts. Students will design their own experiment and test materials using their experimental design and then complete an additional teacher provided experiment.

Draw a labeled design including any applicable features that will entice NASA to purchase this spacesuit design for their astronauts.

1. What is your suggested thermal insulative material for the design?

2. Why did you choose this material, include data from class experiments (remember to talk about thermal energy).

3. Graph collected data on your suggested materials performance during the experiment.

Appendix F: 5th grade Thermal Insulators Test

Name _____

1. Name three tools that can measure thermal energy.

2. What is a thermal Insulator?

3. Provide an example of an insulator, conductor, and location of a temperature sensor.

4. What makes one material a better thermal insulator than another?

5. How does humidity or wetness affect a material's ability to insulate?

6. What is a conductor?

7. Find the mean, median, mode, and range for the following temperatures: 100, 95, 93, 90, 90, 88, and 81.

8. Construct a line graph that represents the following temperature readings: 100, 95, 93, 90, 90, 88, and 81.

9. Name three ways in which you depend on insulation.

Appendix F: 8th grade Thermal Insulators Test

Name _____

1. Name three tools that can measure thermal energy.

2. What is a thermal Insulator?

3. Provide an example of an insulator, conductor, and location of a temperature sensor.

4. What makes one material a better thermal insulator than another?

5. How does humidity or wetness affect a material's ability to insulate?

6. What is a conductor?

7. Find the mean, median, mode, and range with and without the outlier for the following temperatures: 100, 95, 93, 90, 90, 88, and 81. Identify the outlier.

8. Construct a scatter plot that represents the following temperature readings: 100, 95, 93, 90, 90, 88, and 81 and determine if there is a positive, negative or no correlation. Remember to label the graph and axis.

9. Name three ways in which you depend on insulation.