The Dayton Regional
STEM Center
Science, Technology, Engineering and Math

NDEP
NATIONAL DEFENSE EDUCATION PROGRAM
BUILDING AMERICAN STRENGTH IN SCIENCE AND ENGINEERING

Sensors

Let's Heat Things Up

Grade Levels: 9 - 12

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

Topics: Physical Science, Science and Technology, Scientific Inquiry, Scientific Ways of Knowing

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

Main Problem / Essential Question

How can water be heated to safe human consumption levels without the aid of electricity or combustible materials?

Summary

This activity will explore heat transfer and temperature conversion. Students will conduct Internet based inquiries on conduction, convection, and radiation to understand a thermal sensor lab. Use of the data collected from this lab will be implemented in the investigation, design, and testing of solar cooker. Through a provided scenario students employ their knowledge to solve a humanitarian issue that much of the world faces: harnessing a clean water supply. Implementation of an included math lab helps students understand the conversion between Celsius and Fahrenheit and how change in temperatures can be seen mathematically by using the equation for the slope of a line.

Regardless of how this project is applied in the classroom all students should gain an understanding of temperature sensors, thermal characteristics of different materials and how to record, analyze, graph and interpret data (either by hand or electronically) and communicate the results. Furthermore, they should understand how to convert temperature measurements from one scale to another.

Big Ideas / Focus

Heat transfer occurs by conduction, convection or radiation. Conduction is the movement of heat energy through a solid. This occurs as a result of collisions between atoms and molecules in the split which results in the transfer of kinetic energy from the fast vibrating hot atoms to the slow vibrating cold atoms. Convection is the transfer of heat through the circulation of currents from a hot to cold region. Radiation is energy that is transmitted in the form of rays, particles or waves. Examples include UV rays and x rays. Through exploration of conduction and convection students will use sensors to study heat change and variables affecting the change in temperature to design and build a solar cooker. The engineering challenge of the solar cooker is to build a unit that can boil water and therefore solve the humanitarian dilemma the student's have been posed with.

The three temperature scales used in physics are Celsius, Fahrenheit, and Kelvin. Students will learn the freezing and boiling points for all three scales. Students will also learn that to derive the formula to convert from °F to °C you must first realize that 32°F equals 0°C and that 212°F equals 100°C. The relationship is linear so, °C = m °F + b where ***m*** is the conversion factor and ***b*** is the adjustment or intercept. Using the points we already know results in °C = 5/9* (°F - 32). For °C to °F, you reverse the positions or take the previous conversion and solve for °F. This results in °F = 9/5 * °C + 32.

The change in temperature can be viewed using the equation for how to find a slope, use $(y_2-y_1)/(x_2-x_1)$. Given the points (0, 32) and (100, 212) on your coordinate graph, calculate (100-0) / (212-32) which yields the ratio 9/5.

Prerequisite Knowledge

Students need to be able to do basic math conversions.

Students need a working knowledge of TI graphing calculators.

Students need to be able to conduct effective Internet investigations.

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 9- Benchmark A: Describe that matter is made of minute particles called atoms and atoms are comprised of even smaller components. Explain the structure and properties of atoms.	11. Explain how thermal energy exists in the random motion and vibrations of atoms and molecules. Recognize that the higher the temperature, the greater the average atomic or molecular motion, and during changes of state the temperature remains constant.
Grade 9- Benchmark F: Explain how energy may change form or be redistributed but the total quantity of energy is conserved	17. Demonstrate that thermal energy can be transferred by conduction, convection or radiation (e.g., through materials by the collision of particles, moving air masses or across empty space by forms of electromagnetic radiation).

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 9- Benchmark A: Explain the ways in which the processes of technological design respond to the needs of society.	2. Identify a problem or need, propose designs and choose among alternative solutions for the problem.

Grade 9- Benchmark A: Explain the ways in which the processes of technological design respond to the needs of society.	3. Explain why a design should be continually assessed and the ideas of the design should be tested, adapted and refined.
Grade 10- Benchmark B: Explain that science and technology are interdependent; each drives the other.	1. Cite examples of ways that scientific inquiry is driven by the desire to understand the natural world and how technology is driven by the need to meet human needs and solve human problems.
Grade 12- Benchmark A: Predict how human choices today will determine the quality and quantity of life on Earth	1. Explain how science often advances with the introduction of new technologies and how solving technological problems often results in new scientific knowledge.

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 9- Benchmark A: Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.	4. Decide what degree of precision based on the data is adequate and round off the results of calculator operations to the proper number of significant figures to reasonably reflect those of the inputs. 5. Develop oral and written presentations using clear language, accurate data, appropriate graphs, tables, maps and available technology. 6. Draw logical conclusions based on scientific knowledge and evidence from investigations.
Grade 10- Benchmark A: Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.	2. Present scientific findings using clear language, accurate data, appropriate graphs, tables, maps and available technology. 3. Use mathematical models to predict and analyze natural phenomena. 4. Draw conclusions from inquiries based on scientific knowledge and principles, the use of logic and evidence (data) from investigations
Grade 12- Benchmark A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from the data.	5. Use appropriate summary statistics to analyze and describe data.

Scientific Ways of Knowing Standard
Students realize that the current body of scientific knowledge must be based on evidence, be predictive, logical, subject to modification and limited to the natural world. This includes demonstrating an understanding that scientific knowledge grows and advances as new evidence is discovered to support or modify existing theories, as well as to encourage the development of new theories. Students are able to reflect on ethical scientific practices and demonstrate an understanding of how the current body of scientific knowledge reflects the historical and cultural contributions of women and men who provide us with a more reliable and comprehensive understanding of the natural world.

Grade 9- Benchmark A: Explain that scientific knowledge must be based on evidence; be predictive, logical, subject to modification and limited to the natural world.	2. Illustrate that the methods and procedures used to obtain evidence must be clearly reported to enhance opportunities for further investigations.
Grade 11- Benchmark A: Explain how scientific evidence is used to develop and revise scientific predictions, ideas or theories.	2. Apply scientific inquiry to evaluate results of scientific investigations, observations, theoretical models and the explanations proposed by other scientists.

Preparation for Activity

Photocopy all necessary worksheets

Arrange for class access to Internet for Days 1 and 5

Gather all necessary lab materials

Gain access to TI Connect Software

Critical Vocabulary

Conduction - the ability of heat to flow through a material when objects at different temperatures are placed in contact

Convection - is the transfer of heat through by the motion or circulation of a fluid (gas or liquid) that contains thermal energy

Heat - the amount of thermal energy transferred between two objects due to a temperature difference

Radiation - is the flow, emission, or propagation of energy by electromagnetic waves or particles

Solar cooker - a device that uses sunlight as its energy source to cook

Temperature - is the measurement of the average kinetic energy of the molecules in an object or system

Thermal energy - this energy exists in the random motion and vibrations of atoms and molecules. This energy is proportionate to the temperature of the molecule.

Timeframe

Day	Time Allotment	Activities
1	50 minutes	Pre-Test Internet Research on conduction, convection, and radiation as well as completion of accompanying lab sheet "Heat Inquiry".
2	50 minutes	Math application: Explore the conversion factors of Celsius to Fahrenheit and vice versa. Calculate temperature differences and compare temperature scales using TI graphing calculators. This should be a teacher led activity.
3	55 minutes	Sensors Lab
4	50 minutes	Solar Cooker Inquiry & Design
5	55 minutes	Solar Cooker Challenge *(This will take two class periods if you arrange for a guest judge/speaker: in this instance have students build on the first day and test on the second.)*
6	50 minutes	Post Activity Discussion Post-Test

Materials & Equipment

Each lab team will need:
Scrap metal (to serve as plate)
Heat lamp
1 metal stand
2 metal clamps
Beaker (all groups need the same size beaker)
Thermometer
2 temperature sensors
TI Graphing Calculators
Small tabletop fans (optional)
Access to small boxes, foil, and other materials appropriate for solar cooker construction (ex. metal coat hangers, cardboard, foam, duct tape, electrical tape, large paper clips, bind clips, scissors, pliers etc.)
Access to TI Connect Software

Safety and Disposal

Verify students have proper pedagogy for lab equipment.

Students will be dealing with hot metal proper safety procedures should be in place.

Pre-Activity Discussion

The importance of a clean water source is necessary for healthy living. Through history humans have been plagued by disease and pathogens that exist in the water supply. Discuss situations such as natural disasters and third world countries where this concern is a daily issue.

Discuss what the Center for Disease Control (CDC) recommendations for water safety. The CDC lists multiple ways in which water can be made safe for our consumption. These ways include chemical disinfection, use of specific water filters, or boiling water vigorously for one minute and allowing it to cool to room temperature (do not add ice). At altitudes above 6,562 ft water must be boiled for three minutes. More information can be found at: http://wwwnc.cdc.gov/travel/content/water-treatment.aspx

Teacher Instructions

Day 1: Assign student groups, of three to four individuals, and have them choose their roles. For the duration of these activities each student will assume leadership of one of the following segments; heat transfer inquiry, sensors lab, solar cooker inquiry, and solar cooker lab. (If you have groups of three students the inquiry can be led by the same individual).

Students will conduct Internet inquiry on heat transfer and complete appropriate section of accompanying lab packet, "Let's Heat Things Up". After Internet inquiry is complete lead a brief discussion to solidify understand and application of conduction, convection, and radiation.

Day 2: Math application to explore the conversion factors of Celsius to Fahrenheit and vice versa. Teacher should provide the equations for the students to use in temperature conversions. Use of TI graphing calculators and TI connect software will enhance this activity. This should be a teacher led activity.

Teacher Note: When converting the -40° Fahrenheit to Celsius students are going to discover that -40° is the same value on both scales. Many scientists and engineers use alternate conversion equations to take advantage of this fact.

F→→C	and	C→→F
$(F+40) \times 5/9 - 40 = C$		$(C+40) \times 9/5 - 40 = F$

Day 3: Introduce students to scenario and have student groups conduct Sensors Lab.

Scenario:

"You are an environmental engineer who has volunteered to help victims after a catastrophic natural disaster. Your team is one of the first responders to a remote community affected by the disaster. Like many surrounding communities the local water source has been contaminated. With no source of power the natives are in need of a safe water supply to survive. There are limited resources available to you and the survivors. You are tasked with establishing safe drinking water. Your location is near the equator, where the average temperature is 85° Fahrenheit.

The supplies are limited. Materials available for your use include: multiple pieces of scrap metal such as aluminum, scissors, pliers, cardboard containers of various sizes, first aid kit, and various fasteners that can be salvaged from the building debris."

Preliminary Experiment Procedure:

1. Suspend the metal plate perpendicularly between two lab stands. Use the clamps to secure the plates, but place the clamps as close to the top of the metal plate to reduce the heat transfer to the stands. Set the heat lamp up so that it is about 30.5 cm (12 ") from the metal plate and directed at the center of the plate but do not turn it on yet. Affix the temperature sensor to the center of the back of the metal plate, and place the second temperature sensor approximately 2 cm (3/4") from the back of the plate, near but not directly behind the first sensor. Allow the set-up to sit for at least five minutes so the plate and sensors can reach ambient temperature.

2. After five minutes, take one plate and one air temperature measurement with the lamp off. Turn the lamp on and take additional plate and air temperature measurements every minute for ten minutes. Students should write down their measurements. Turn the lamp off and allow the plate to cool back to ambient temperature (you may use a fan to expedite this process).

3. Cover the side of the metal plate that faces the heat lamp with aluminum foil. Take temperature measurements from sensors, turn the lamp on and take temperature measurements immediately and then every minute for ten minutes. Cool the plate as done previously and remove the aluminum foil from plate.

4. Now cover the side of the metal plate, which faces away from the heat lamp, and repeat the experiment.

5. Students should graph time and temperature for each sensor for all three plates and compare the results. Students should graph their findings on their graphing calculators and print them for teacher review. (Use of TI graphing calculators & TI connect software)

6. Complete any remaining questions in "sensors lab".

Day 4: Solar Cooker Inquiry: The students should identify on the Internet and create plans for building solar cookers in preparation for the activity. There are many plans available.

Some resources include: http://solarcooking.org/plans/, http://pbskids.org/zoom/activities/sci/solarcookers.html, http://www1.eere.energy.gov/kids/roofus/pizza_box.html, http://www.re-energy.ca/t-i_solarheatbuild-1.shtml.

Student's worksheet does not include the websites listed above. If you want to guide student Internet inquiry provide the above websites, if not allow students to conduct their own inquiry. Remind students to work as a group to draw out their design for their solar cooker each group will only build one solar cooker.

Teacher Note: Students should have sufficient time to design their cooker. Encourage your students to reflect upon their sensors experiment to determine the best mode of heating their water. Using this information and the solar cooker research students should design or modify an Internet design that they will implement in the following lab.

Day 5: Have each student team use their created design and information obtained from the sensor experiment to design a solar cooker. If there is limited money and supplies for this project, the students can have design parameters which limit the types of materials they can use to foil, boxes, etc (see websites provided for guidelines).

Students will then test their design either by using the heat lamps or natural sunlight by placing the placing a predetermined amount of water in a beaker and attempting to bring it to a boil. The addition of temperature sensors in the solar cooker will allow students to record temperature increase as a function of time.

The instructor may wish to make this a competition, providing a reward for the “best” design, or you can ask the students to bring in food and actually use the cookers to make pizza bagels or other food for students and/or guests.

Invite an engineer or physicist from AFRL Advanced Manufacturing and Materials or Sensors directorate to help judge and critique the solar cookers. Afterward allow your visitor to discuss some of their current research in an applicable field. *(Teacher Note: Make sure you provide your guest speaker with clear expectations of their visit including talking points and a brief overview of your student’s academic level. Also, when implementing this part of the lab. Allow for an extra day for the experiment and judging with guest to happen on as there is not enough time allotted in the current schedule.)*

Day 6: Administer post-test.

Background Information

The Center for Disease Control lists multiple ways in which water can be made safe for our consumption. These ways include chemical disinfection, use of specific water filters, or boiling water vigorously for one minute and allowing it to cool to room temperature (do not add ice). At altitudes above 6,562 ft water must be boiled for three minutes. More information can be found at: http://wwwnc.cdc.gov/travel/content/water-treatment.aspx

Instructional Tips

Monitor student progress during internet inquiry, to assure students are collecting data from reputable sights and not travel blogs.

Verify that students understand the physics of the slow cooker and why the online designs use reflective surface.

Assignment of Student Roles and Responsibilities

Every student in each small group is responsible for performing experimental tests, manipulating equipment safely & properly, recording data, writing results and conclusions. In addition, each student will be assigned one of the following roles:

Role Name	***Brief Description***
Heat Transfer: Head Researcher	Responsible for leadership of Internet research on conduction, convection, and radiation.
Sensors Lab: Head Technician	Responsible for leadership of the sensors lab including gathering materials, leading lab processes, and overseeing lab cleanup.
Solar Cooker: Head Researcher	Responsible for leadership of Internet research on solar cooker design. Responsible for diagramming group design that is needed for later implementation.
Solar Cooker: Head Technician	Responsible for leadership of the solar cooker lab including gathering materials, implementing group design, completion of lab challenge, and overseeing lab cleanup.

Student Instructions

Day	Activity
Day 1	Complete Pre Test Determine Groups & Roles (refer to lab packet) Conduct Heat Transfer Inquiry (refer to lab packet)
Day 2	Math in Action (refer to lab packet) Teacher Led Exploration of Temperature conversion and statistical analysis of temperature change.
Day 3	Sensors Lab (refer to lab packet)
Day 4	Solar Cooker Inquiry (refer to lab packet)
Day 5	Solar Cooker Lab & Trial (refer to lab packet)
Day 6	Complete Post Test

Formative Assessments

Students should be assessed throughout activities. Rubrics are provided for the sensors lab and solar cooker lab. A pre/post test with an accompanying rubric is also provided.

Post Activity Discussion

Discuss forms of heat transfer and examples of each. Have students relate heat transfer to specific parts of their lab.

Discuss how science has helped advance society through the understanding and harnessing of heat transfer. Discuss how heat kills water and food borne pathogens. Discuss how these concepts relate to safe food consumption.

Discuss how student's research relates to current research being conducted by the Air Force, as presented by guest speaker/judge.

Pre-Test / Post-Test

1. The Fahrenheit temperature scale has the freezing point of water at 32 °F and the boiling point at 212 °F. The Celsius temperature scale has the freezing point of water at 0 °C and the boiling point at 100 °C. Derive the conversion formulas for °F to °C and °C to °F.

   To derive the formula to convert from °F to °C you must first realize that 32°F equals 0°C and that 212°F equals 100°C. The relationship is linear so, °C = m °F + b where m is the conversion factor and b is the adjustment or intercept. Using the points we already know results in °C = 5/9 x (°F - 32). For °C to °F, you reverse the positions or take the previous conversion and solve for °F. °F = 9/5 x °C + 32.

   **The conversion factor is the change in Y over the change in X, which is the slope of the line. To find the slope, use $(Y_2-Y_1)/(X_2-X_1)$. Given the points (0, 32) and (100, 212) on your coordinate graph, calculate (100-0) / (212-32) which yields the ratio 9/5.*

Show your work for each of the following conversions.

2. 100^oF = ________ ^oC

   $^oC = (100-32)/1.8$

   $^oC = 37.8$

3. -15^oC = ________ ^oF

   $^oF = 1.8*(-15)+32$

   $^oF = 5$

4. $35\,^oF$ = ________ ^oC

   $^oC = (35-32)/1.8$

   $^oC = 1.67$

Write a complete sentence or two for each of the following.

5. What is conduction? Give an example.

   Conduction is the ability of heat to flow through a material when objects at different temperatures are placed in contact.

   An example is the heating up of a pan on a hot unit

6. What is convection? Give an example.

   Convection is the transfer of heat through by the motion or circulation of a fluid (gas or liquid) that contains thermal energy. An example is an oven heating element warming the air in the confines of the oven.

7. What is radiation? Give an example.

   Radiation is the flow, emission, or propagation of energy by electromagnetic waves or particles. An example is the sun heating the earth.

8. How does thermal energy relate to temperature and how can it be transferred?

   The higher the temperature is, the higher the thermal energy. This energy can be transferred through convection, conduction, or radiation through materials by collision of particles, moving air masses or across empty space by forms of electromagnetic radiation.

9. When you were running the solar sensor experiment,

   a. the sensor behind the plate was being heated by?

   This sensor was mainly being heated by convection.

   b. the sensor on the plate was being heated by?

   This sensor was mainly being heated by conduction

10. How did you apply physics to your problem scenario (the contaminated water)?

We were able to focus solar energy on a beaker of water in order to raise the temperature of the water to boiling. Through boiling the water for 10 minutes *and allowing it to cool at room temperature we killed/denature any bacteria or viruses that were in the contaminated water.*

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Pre- Test/ Post-Test Rubric

1. Derive the conversion formulas for ^{o}F to ^{o}C and ^{o}C to ^{o}F.

4 points	Proper conversions for both ^{o}F to ^{o}C and ^{o}C to ^{o}F were provided
2 points	Proper conversions for one were provided and the other was attempted but incorrect
1 point	Conversions for both were attempted but incorrect

2. 100^{o}F = ________ ^{o}C

2 points	Correct work and correct answer are provided
1 point	Correct work OR correct answer is provided

3. -15^{o}C = ________ ^{o}F

2 points	Correct work and correct answer are provided
1 point	Correct work OR correct answer is provided

4. 35 ^{o}F = ________ ^{o}C

2 points	Correct work and correct answer are provided
1 point	Correct work OR correct answer is provided

5. What is conduction? Give an example.

4 points	Correct definition and correct example are provided
2 points	Either correct definition OR correct example are provided

6. What is convection? Give an example.

4 points	Correct definition and correct example are provided
2 points	Either correct definition OR correct example are provided

7. What is radiation? Give an example.

4 points	Correct definition and correct example are provided
2 points	Either correct definition OR correct example are provided

8. How does thermal energy relate to temperature and how can it be transferred?

4 points	Student states there is a proportional relationship between temperature and thermal energy. AND that energy can be transferred through convection, conduction or radiation. (Student provides all three of the ways that energy can be transferred)
3 points	Student states there is a proportional relationship between temperature and thermal energy. AND that energy can be transferred through convection, conduction or radiation. (Student only provides one or two of the ways that energy can be transferred)
2 points	Student only correctly answers half of the questions
1 point	Student answer demonstrates an understanding that there is a relationship between heat, thermal energy and forms of energy transfer but does not summarize the information into a correct statement

9. When you were running the solar sensor experiment,

a. the sensor behind the plate was being heated by?

b. the sensor on the plate was being heated by?

2 points	Student correctly answers part a and b
1 point	Student correctly answers part a OR b

10. How did you apply physics to your problem scenario (the contaminated water)?

5 points	Student identifies that solar energy raises the temperature of the water to boiling and that after a time frame of 10 minutes all contaminates will be killed/denatured
4 points	Student identifies 4 of the 5 underlined main components above
3 points	Student identifies 3 of the 5 underlined main components above
2 points	Student identifies 2 of the 5 underlined main components above
1 point	Student identifies 1 of the 5 underlined main components above

Rubric

SENSORS LAB RUBRIC

Students should be provided with a copy or access to this rubric.
(You do NOT have to use all categories)

CATEGORY	4	3	2	1
Focus on the task	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.
Collaboration	Almost always listens to, shares with, and supports the efforts of others. Has demonstrated great cooperation.	Usually listens to, shares, with, and supports the efforts of others, generally cooperative.	Often listens to, shares with, and supports the efforts of others, but has been uncooperative at times.	Rarely listens to, shares with, and supports the efforts of other, is generally uncooperative.
Scientific Knowledge	Explanations indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations indicate a basic understanding of scientific principles underlying the construction and modifications.	Explanations do not illustrate any understanding of the scientific principles underlying the construction and modifications.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.

SOLAR COOKER RUBRIC

Students should be provided with a copy or access to this rubric.
(You do NOT have to use all categories).

CATEGORY	4	3	2	1
Concept Inquiry	Relevant information gathered from 2 or more websites.	Relevant information gathered from 1 websites.	Information gathered was irrelevant to the design challenge.	No evidence of inquiry.

Contributions	Routinely provides useful ideas when participating in the group or classroom discussion. Contributes a lot of effort.	Usually provides useful ideas when participating in the group or classroom discussion. A strong group who shows effort!	Sometimes provides useful ideas when participating in the group or classroom discussion. A satisfactory group member who does only what is required.	Rarely or never provides productive ideas when participating in the group or classroom discussion.
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.
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.
Collaboration	Almost always listens to, shares with, and supports the efforts of others. Has demonstrated great cooperation.	Usually listens to, shares, with, and supports the efforts of others, generally cooperative.	Often listens to, shares with, and supports the efforts of others, but has been uncooperative at times.	Rarely listens to, shares with, and supports the efforts of other, is generally uncooperative.
Construction: Material usage	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Experimentation (Determine temperature requirement. Recommended: 100°F)	Followed through on experiment after the build and successfully measured raised temperatures inside solar cooker that met design requirements.	Followed through on experiment after the build and successfully measured raised temperatures inside solar cooker however temperature did not meet design requirements.	Followed through on experiment after the build but solar cooker was either non functional or temperature readings from within solar cooker were not recorded.	Solar cooker was not finished enough to be tested.

Technology Connection

The **ADISC** Model created by ITEL

Integration Model	Application Description
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	TI Graphing Calculators: Math TI Connect Software: Math
Technology that supports students and teachers in conducting **inquiry**, including the effective use of Internet research methods	Internet: Lesson Inquiry Sensors: Thermal Readings
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	Heat Lamp: Simulating Solar Power
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	TI Connect Software: allows students to share data with their teacher and peers

Interdisciplinary Connection

This activity currently integrates science, and math. Math standards could be further addressed by comparison of three temperature scales or further analysis and graphing of data.

Data and scientific concepts could be used for technical writing standards.

The concept of contaminated water / water borne pathogens can be linked to historic plagues and disease outbreaks such as Cholera, the affects of these outbreaks have great historical significance on European history of the 19th century.

Home Connection

Students can investigate how many sensors they rely on in their daily life. Examples include; motion activated sensors, light sensors, oven temperature sensors, pressure sensors in tires, etc.

Differentiated Instruction

Product: During Solar Cooker Inquiry websites can be provided or the teacher can expect the students to compile information without this direction. Also, teacher can implement explicit design specifications that may require students to construct an entirely original design.

Product: Students can also be required to share their solar cooker design and data from the cooker in a formal report, presentation, and video commercial for their cooker, or poster.

Product and Content: Students could research parabolic cookers and use math concepts in their design and analysis of these cookers. They can choose to build this type of solar cooker or use geometric relations to design and build a box type solar cooker.

Extension

The solar cooker concept can be extended into food preparation or a food challenge such as making the perfect S'more.

Students could create a graphical comparison for Celsius, Fahrenheit, and Kelvin scale.

Students can investigate current research the field of thermal energy including research and implementation. An example of implementation is military to harness "green energy" to save money. http://articles.latimes.com/2009/apr/26/local/me-army-green26. This article discusses current Army efforts to use thermal energy research to reduce consumption and embrace energy alternatives.

Connection

Civil Engineers can specialize in water supply and sanitation. These engineers are tasked with designing, implementing and maintaining society's water and waste treatment and storage.

There is a diverse amount of health officials, medical doctors, biologists, virologists, and chemists that study bacteria and viruses that affect our society.

Advanced Manufacturing and Materials has a group (RXS) that researchs and designs deployable base energy sources. This group is tasked with creating a portable infastructure that may need to provide not only power but also communication, sanitation, and HVAC (heating, ventiliation, and air conditioning) needs for the entire temporary base. In the past, these bases have relied on gas generators but now this research group is studying innovative power sources such as solor cells on tents and biomass fuel sources.

Teacher Note: The current focus on biomass fuel sources is to create algae pits and burn the algae as fuel.

The Propulsion directorate is researching nuclear thermal generator propulsion. This is analogous to the solar cooker technology in this lesson. The idea is a new rocket engine that uses a nuclear reactor, like the sun in the lesson, as its power source. The energy from the power source heats up a liquid, similar to the water in this lesson. Energy is then transferred from the liquid to a gas. This energy transfer causes an increase in pressure and temperature in the gas. A valve then controls the release of this gas which serves as the propulsion for the rocket.

Additional Resources

Resource:	**Purpose and Application:**
Solar Cooker	http://solarcooking.org/plans/, http://pbskids.org/zoom/activities/sci/solarcookers.html, http://www1.eere.energy.gov/kids/roofus/pizza_box.html, http://www.re-energy.ca/t-i_solarheatbuild-1.shtml.
Center for Disease Control: Water treatment methods.	http://wwwnc.cdc.gov/travel/content/water-treatment.aspx
LA Times article on military base efforts to "go green".	http://articles.latimes.com/2009/apr/26/local/me-army-green26

Credits

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Teacher Reflections

Were students focused and on task throughout the lesson?

If not, what improvements could be made the next time this lesson is used?

Were the students led too much in the lesson or did they need more guidance?

Did the students learn what they were supposed to learn?

How do you know?

How did students demonstrate that they were actively learning?

Did you find it necessary to make any adjustments during the lesson?

What were they?

Did the materials that the students were using affect classroom behavior or management?

What were some of the problems students encountered when using the …?

Are there better items that can be used next time?

Which ones worked particularly well?

Additional Comments

NAME ___________________________________

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Let's Heat Things Up Test

1. The Fahrenheit temperature scale has the freezing point of water at 32 ^{o}F and the boiling point at 212 ^{o}F. The Celsius temperature scale has the freezing point of water at 0 ^{o}C and the boiling point at 100 ^{o}C. Derive the conversion formulas for ^{o}F to ^{o}C and ^{o}C to ^{o}F.

Show your work for each of the following conversions.

2. 100^{o}F = _________ ^{o}C

3. -15^{o}C = _________ ^{o}F

4. 35 ^{o}F = _________ ^{o}C

Write a complete sentence or two for each of the following questions.

5. What is conduction? Give an example.

6. What is convection? Give an example.

7. What is radiation? Give an example.

8. How does thermal energy relate to temperature and how can it be transferred?

9. When you were running the solar sensor experiment:
    a. the sensor behind the plate was being heated by?
    b. the sensor on the plate was being heated by?

10. How did you apply physics to your problem scenario (the contaminated water)?

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Let's Heat Things Up Unit

Student Roles

Role Name	***Brief Description***
Heat Transfer: Head Researcher ______________________	Responsible for leadership of internet research on conduction, convection, and radiation.
Sensors Lab: Head Technician ______________________	Responsible for leadership of the sensors lab including gathering materials, leading lab processes, and overseeing lab cleanup.
Solar Cooker: Head Researcher ______________________	Responsible for leadership of internet research on solar cooker design. Responsible for diagramming group design that is needed for later implementation.
Solar Cooker: Head Technician ______________________	Responsible for leadership of the solar cooker lab including gathering materials, implementing group design, completion of lab challenge, and overseeing lab cleanup.

Day	**Activity**
Day 1	Pre-Test & Heat Transfer Inquiry
Day 2	Math at Work
Day 3	Sensors Lab
Day 4	Solar Cooker Inquiry
Day 5	Solar Cooker Lab & Trial
Day 6	Post-Test

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DAY 1: Heat Transfer:

Definition	**2 Examples of this process**
Convection	
Conduction	
Radiation	

1. What temperature does the Center for Disease Control state that contaminated water must reach to be considered safe for consumption?

____

____

____

2. What happens to atoms when they are heated?

____

____

____

3. How does heating water and food make it safe?

____

____

____

4. What is thermal energy? How does it relate to temperature? How can it be transferred?

____

____

____

____

5. How has science improved our lives with the discovery of radiation?

____

____

____

6. What are the three temperature scales used in Physics?

____

____

____

7. Which temperature scale is considered the absolute temperature scale and why?

____

____

____

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Math At Work

Directions: With the aid of your instructor develop an equation to convert between Celsius and Fahrenheit.

Challenge: Explore how this equation can be used to find the slope of a line.

Complete the graph below

	Celsius = C	***Fahrenheit = F***	***Kelvin= K***
Freezing			
Boiling			
Temperature	-15°		
Temperature		85°	
Temperature		100°	
Temperature	20°		
Temperature		-40°	

Use space below to show your work:

NAME ___________________________________

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Sensors Lab

✓ the boxes as you complete the steps

Suspend the metal plate perpendicularly between two lab stands.

Use the clamps to secure the plates, (place the clamps as close to the top of the metal plate to reduce the heat transfer to the stands).

Set the heat lamp up so that it is about 30.5 cm (12 “) from the metal plate and directed at the center of the plate. **Do not turn it on!**

Affix the temperature sensor to the center of the back of the metal plate.

Affix a second temperature sensor approximately 2 cm (3/4”) from the back of the plate, near but not directly behind the first sensor. This sensor will provide the air temperature reading.

After 5 minutes (the plate and sensors can reach ambient temperature). Take your first measurement. Record your findings in minute 0 as this represents the steady state reading before you test your variable (the heat lamp).

Turn the lamp on.

Take plate and air temperature measurements every minute for ten minutes. Record below.

Time	Plate Temperature (Sensor 1)	Air Temperature (Sensor 2)
Minute 0		
Minute 1		
Minute 2		
Minute 3		
Minute 4		
Minute 5		
Minute 6		
Minute 7		
Minute 8		

Minute 9		
Minute 10		

Turn the lamp off and allow the plate to cool back to ambient temperature (you may use a fan to expedite this process).

PART TWO

Cover the side of the metal plate that faces the heat lamp with aluminum foil.

Turn the lamp on and take temperature measurements immediately and then every minute for ten minutes. (Note: Minute 0 is before you turn on test the variable: the heat lamp. This reading is called your steady state reading.)

Time	**Plate Temperature covered with foil on the side of the heat lamp (Sensor 1)**	**Air Temperature (Sensor 2)**
Minute 0		
Minute 1		
Minute 2		
Minute 3		
Minute 4		
Minute 5		
Minute 6		
Minute 7		
Minute 8		
Minute 9		
Minute 10		

Cool the plate.

Remove the aluminum foil from plate.

PART THREE

Cover the side of the metal plate, which faces away from the heat lamp, and repeat the experiment.

Record your minute 0 reading for your steady state reading.

Turn the lamp on and take temperature measurements immediately and then every minute for ten minutes.

Time	Plate Temperature covered with foil on opposite side of the heat lamp (Sensor 1)	Air Temperature (Sensor 2)
Minute 0		
Minute 1		
Minute 2		
Minute 3		
Minute 4		
Minute 5		
Minute 6		
Minute 7		
Minute 8		
Minute 9		
Minute 10		

Cool the plate.

Remove the aluminum foil from plate.

Minute zero serves as your ___________________________________ in each experiment.

PART FOUR

Graph time and temperature for each sensor for all three plates.

What similarities can you conclude when you compare the graphs?

____

What differences do you see between the graphs above?

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Solar Cooker Inquiry

Engineering Challenge:

"You are an environmental engineer who has volunteered to help victims after a catastrophic natural disaster. Your team is one of the first responders to a remote community affected by the disaster. Like many surrounding communities the local water source has been contaminated. With no source of power the natives are in need of a safe water supply to survive. There are limited resources available to you and the survivors. You are tasked with establishing safe drinking water. Your location is near the equator, where the average daily temperature is 85° Fahrenheit.

The supplies are limited. Materials available for your use include: multiple pieces of scrap metal such as aluminum, scissors, pliers, cardboard containers of various sizes, first aid kit, and various fasteners that can be salvaged from the building debris."

Directions: Conduct an Internet inquiry of solar cookers to complete the following questions. Use the information you learn to design a solar cooker that your group will test.

What is a solar cooker?

____

____

____

How does a solar cooker use thermal energy?

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____

____

____

Why are most solar cookers covered in a reflective surface?

____

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What is the goal of your solar cooker and why?

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How can you apply the results of the sensor lab to your solar cooker design?

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Solar Cooker Design

(Remember to label your diagram and refer to the engineering challenge for available supplies)

What are two ways that you can measure if your solar cooker will get the job done?

____

____

____

NAME ________________________________

DATE________________________________

Solar Cooker Lab & Trial

Engineering Challenge:

"You are an environmental engineer who has volunteered to help victims after a catastrophic natural disaster. Your team is one of the first responders to a remote community affected by the disaster. Like many surrounding communities the local water source has been contaminated. With no source of power the natives are in need of a safe water supply to survive. There are limited resources available to you and the survivors. You are tasked with establishing safe drinking water. Your location is near the equator, where the average daily temperature is 85° Fahrenheit.

The supplies are limited. Materials available for your use include: multiple pieces of scrap metal such as aluminum, scissors, pliers, cardboard containers of various sizes, first aid kit, and various fasteners that can be salvaged from the building debris."

Describe how your solar cooker will heat the water (refer to transfer of thermal energy).

____

____

____

✓ the boxes as you complete the steps

- Using teamwork and group diagram assemble the solar cooker
- Place a sensor inside your solar cooker to record the temperature every minute for ten minutes: graph this.
- Setup group solar cooker in test location.
- Place provided beaker of water in solar cooker
- Immediately start recording data in the following table using the installed sensor.

Time	Temperature sensor reading	Visual Observation of Water
Minute 0		
Minute 1		
Minute 2		
Minute 3		

Minute 4		
Minute 5		
Minute 6		
Minute 7		
Minute 8		
Minute 9		
Minute 10		

Graph results:

When did your water reach the proper temperature to start the sterilization process (100°F)? (If your water never reached this temperature, extrapolate from the graph when you expect that it would.)

____

____

____

How does the transfer of thermal energy relate to this lab experiment?

____

____

____

____

Why should a design be continually assessed, adapted, and refined?
(Hint: Think about what you have learned about your design now that you have tested it.)

____

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