Heat Transfer

CEPA Overview

Heat Transfer is a sequence of six major activities requiring approximately one week (4 to 6 class periods and homework) to complete. The major activities are:

- **Activity 1:** Students individually or in small groups research methods of heat transfer online. They discuss what they have learned about conduction, convection, and radiation *(student-guided learning).*
- **Activity 2:** Teachers check student understanding of methods of heat transfer via ungraded quizzes, interviews, or class discussion *(formative assessment evidence gathering, feedback, and adjustment).*
- **Activity 3:** In small groups, students design and conduct an experiment to determine which of two fabrics better protects against the winter cold *(performance activity)*.
- **Activity 4:** After class discussion of designs, students individually write up a formal lab report of their experiment *(graded summative product).*
- **Activity 5:** Teachers, via questioning, lead class discussion of how methods of heat transfer played a role in the design and implementation of the research *(formative assessment reflection and reinforcement).*
- **Activity 6:** Students individually research how a home heating system works and write a paper describing a home heating system and how different methods of heat transfer are involved *(graded summative product).*

Grade Level(s): 6-8

Primary Concepts and Skills to Be Developed and/or Applied

- methods of heat transfer – conduction, convection, radiation
- basics of experimental design, incl. dependent and independent variables; control of variables; data collection, display, and interpretation
- online research of a topic
- expository writing

Secondary Concepts and Skills Addressed

- problem solving
- use/reading of instruments
- collaboration

Link to Standards/Learning Targets

Next Generation Science Standards Set MS-PS3: Energy

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

Science Practices

- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data

Disciplinary Core Ideas PS3.B: Conservation of Energy and Energy Transfer

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (Note: Clicking on this core idea in NGSS accesses further information, specifically referencing conduction, convection, and radiation.)

Crosscutting Concepts

- Energy and Matter – The transfer of energy can be tracked as energy flows through a designed or natural system.

Common Core State Standards in ELA/Literacy

WHST.6-8.7: Conduct short research projects to answer a question (including self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6-8.2: Write informative/explanatory text to examine a topic and convey ideas, concepts, and information through the selection, organization and analysis of relevant content. (a-f)

W.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

General CEPA Instructions

CEPAs are intended to supplement or replace lessons within the existing curriculum. A great deal of latitude is left to the individual teacher as CEPAs for the most part are not scripted, and CEPA directions do not present the specific foundational content and skills to be addressed. This foundational knowledge is readily accessed through textbook use, internet searches, and online instructional tools such as the Khan Academy or other online resources. Some CEPAs recommend the use of particular resources, but for some activities, teachers may choose alternate resources or approaches. However, every CEPA includes steps or activities that yield scorable student work for summative purposes (e.g., grading). Directions for those activities should be followed closely in situations in which comparability of results across classes, schools, or

districts is important. It is up to the teachers to decide how some directions are to be presented to students – e.g., verbally or by printed direction sheets prepared by the teachers.

Instructions for *Heat Transfer*

<u>Activity 1</u>: Students individually or in small groups research methods of heat transfer online. They discuss what they have learned about conduction, convection, and radiation *(student-guided learning).*

- Teachers should form student groups of 3 to 4, and direct them to do an internet search for methods of heat transfer. Students may or may not work individually initially, but they must discuss their findings within their groups. The initial information gathering step may be accomplished as homework. (To maximize the likelihood of success for all groups, teachers might consider such factors as student interactions, work habits, prior achievement, and others in creating heterogeneous groups for this and a later activity.)
- Students should be directed to determine answers to the following three questions:
    - What are the three methods by which heat is transferred from one place or object to another?
    - How does each method work?
    - What are three examples of each method?
- Students should discuss their findings to come up with their best answers to the questions, and each student should take notes on what they agreed.

<u>Activity 2</u>: Teachers check student understanding of methods of heat transfer via ungraded quizzes, interviews, or class discussion *(formative assessment evidence gathering, feedback, and adjustment).*

- The focus should be on the answers to the three questions in Activity 1. If whole class discussion is used, a spokesperson from each group should be contributing answers.
- As a formative assessment activity, student responses should not count toward course grades. Instead, misconceptions should be addressed immediately either by the teacher or other students.

<u>Activity 3</u>: In small groups, students design and conduct an experiment to determine which of two fabrics better protects against the winter cold *(performance activity).*

- Materials needed by each group:
    - 5 containers: 4 metal (e.g., coffee cans) and 1 plastic (food storage); two metal identical and the one plastic the same capacity as the two (preferably same shape)
    - lids for each container with small hole (or crossed slits) in the center of each lid to hold temperature probe and small enough to hold probe securely to prevent sliding
    - large beaker, measuring cup, or other container for measuring water

  - access to hot water
  - rectangular scraps of two different fabrics, large enough to wrap around containers (e.g., wool, linen, garbage bag plastic) – different groups can have different fabrics
  - rubber bands to secure fabrics around containers
  - timer or access to clock with second hand
- Students should be directed to work in their small groups to ***plan an investigation to determine which of two fabrics would be better for a coat to protect them against cold winter temperatures***. Each student should have a copy or the Activity 3 Worksheet for this. (See Appendix A.) Also, the students should be designing the investigation with the required materials (or a list of them) in front of them.
- Teachers should check each group's plan to see that it is safe and will generate some meaningful data. The investigation design does not need to be perfect (e.g., control for all possible variables that might be controlled), and minor flaws should not be corrected. If a design is completely flawed (e.g., not involving the measurement of heat loss), the teacher can ask the group general questions that will lead students to a better design – e.g., How will you know if the fabric slows heat loss? Teachers should also make sure every group member has a job.
- Once a group's design is "approved" by the teacher, the group may proceed then or in a later class to conduct the investigation, still using the Activity 3 Worksheet for recording data.

Activity 4: After class discussion of designs, students individually write up a formal lab report of their experiment *(graded summative product).*

- At the start of this activity, teachers should display or hand out an outline showing the major sections of a lab report and their basic content. Variations of the display below can be used, but they should cover the same content in some way.
  - Statement of the Problem
    - Research question
    - Hypothesis
  - Procedures
    - Detailed description of how the investigation was conducted
    - Variables controlled and manipulated (independent and dependent variables
    - Measurement/data collection procedures
  - Results/Findings
    - Data display in the form of tables or graphs
    - Brief description of the data display – what it contains
  - Conclusions
    - Whether data supports hypothesis or not

    - Answer to research question
    - Discussion of difficulties encountered in conducting experiment, limitations of the study, and ways it could have been improved
- Teachers should ask some or all of the student teams to describe their investigation(s) to the class, and class discussion should address design and implementation issues.
- Teachers should direct students to work independently to write up their lab reports which will be scored and counted toward their grades. (See scoring rubric in Appendix B.) Yielding student work products demonstrating individual student learning, this activity should be completed in class. (Note: Students should be told that their lab reports will be graded, but that problems encountered during their investigations, poor designs or conclusions will not count against them if they effectively deal with the issues in their discussion – the third bullet in the outline above.)
- Teachers should collect the students' lab reports and score them using the Lab Report Rubrics in Appendix B.

Activity 5: Teachers, via questioning, lead class discussion of how methods of heat transfer played a role in the design and implementation of the research *(formative assessment reflection and reinforcement).*

- This class period is an opportunity for the teacher to both debrief the students on their experiences during their investigations and reinforce their understanding of methods of heat transfer. Before doing so, however, the teacher should ask the students, "What is actually happening when a cup of hot coffee cools off and when a glass of cold soda warms up, and how does a thermos bottle slow these processes down?"
- Having at least perused the students' lab reports (if time has not permitted the completion of scoring) or having scored them, the teacher should be able to identify particularly innovative or interesting or superior things various team members have done either in conducting the investigations or writing the lab reports. The teacher should call on students asking them to explain to the class the noteworthy things the teacher identified. Such things might include:
    - the control of a less obvious variable that many teams did not control,
    - a particularly effective graphic display of data,
    - an insightful suggestion about ways an investigation could have been improved.
- Based on student contributions, the teacher should make a list (visible to the students) of the many variables that could have been controlled during the experiments. It could include such factors as
    - the initial temperature of water in the two containers,
    - the volume of water in the containers,
    - the size, shape, and material of the containers,
    - how the fabrics were wrapped around the containers,

  - the height of the thermal probe tips within the containers
  - the distance of the thermal probe tips from the sides of the containers.
- If the last two factors listed above are provided by the students, the teacher should ask why they matter. If they are not raised, then the teacher should ask the class, "Why is it important that the tips of the thermal probes be placed at the same height within the containers?" or "Why is it important that the tips of the thermal probes be placed the same distance, if any, from the sides of the containers? If no student can answer these, then the teacher can ask, "What method of heat transfer would be a concern in each case." (Answers: convection and conduction, respectively.) The answers should be explained by students or the teacher.
- At this point, the teacher should ask any further questions he/she would like to ask to check on the students' understanding of convection, conduction, insulation, etc. and to correct any misconceptions.
- The first step of Activity 6 can be started at this time.

Activity 6: Students individually research how a home heating system works and write a paper describing a home heating system and how different methods of heat transfer are involved *(graded summative product).*

- The initial Activity 6 assignment can be completed either in class if adequate computer resources are available or out of class, perhaps as homework. The assignment is:

  There are different kinds of home heating systems. They use different energy resources or fuels, and they can use different equipment and operate very differently. Your assignment is to identify a particular type of home heating system and research how it works. Take detailed notes during your research because you will be writing about the system later.

- The following prompt should be provided to students at the start of the class period during which they will write their essays.

  Write a detailed explanation of how the home heating system you researched works. Describe the entire system in detail, and explain how different methods of heat transfer are involved. You may refer to your notes. Your essay will be scored for the quality of your explanation, your understanding of heat transfer methods, and your writing skill.

- Teachers should collect the student essays and score them using the rubrics for them in Appendix B.

Appendix A

Activity 3 Worksheet

Your group should answer the questions on this worksheet together. Each member of the group should write the group's answers on his/her own worksheet. The information you write on this sheet will help you write your lab report.

Your job is to design an investigation to determine which of two fabrics is better for a winter coat. You may use any of the materials provided. Answer the following questions to plan your investigation.

1. What question will the investigation attempt to answer? (This is your research question.)

2. What is your hypothesis?

3. How will you test your hypothesis? Describe your experimental procedures in detail. Be sure to include how you will control for variables that could inappropriately affect your results.

4. What data will you collect?

Data Collection Space (You will use this space later to record data when you are conducting your investigation.):

5. Each person in your group should have a role during the investigation. Here are some roles:
   Data recorder – records the data collected during the investigation
   Instrument reader – reads the instruments and tells the data recorder what information should be written on the data collection sheet
   Assembler – puts together the materials for the investigation
   Timer – watches the clock to determine when measurements should be taken and recorded

   Decide who will fill each role during your investigation.

6. Ask your teacher to approve the plans for your investigation.

7. Proceed with your investigation, making sure that when data collection is completed, every group member has recorded the data on his or her own worksheet at the top of this page.

Appendix B

Scoring Rubrics

(Note: For the first three rubrics below, which pertain to a student's lab report, the teacher should first read through the entire report, pointing out via annotations any issues in the design and implementation of the investigation. In assigning scores, the teacher should rely heavily on the student's discussion of problems and ways the investigation could have been improved. In other words, a student could still receive high scores if his or her team conducted a flawed investigation as long this discussion describes a study that would effectively address the research question.)

Lab Report – Design/Procedures

Score	Description
4	The report describes a set of procedures that would effectively lead to an appropriate conclusion regarding the research question or hypothesis. • The description is clear and detailed making the investigation replicable. • The report makes it clear that rate of heat loss is the focus (dependent variable), fabric is the manipulated (independent) variable, and at least three important variables* are controlled, including size and type of container.
3	The description of workable** procedures is mostly complete, but characterized by some vagueness or information (e.g., controlled variables) left for reader to infer – e.g., identical containers identified, implying same volume of water; or initial temperature of water must be assumed).
2	Heat loss with respect to two fabrics is the focus, but description of procedures vague or clearly incomplete making replicability difficult.
1	Report does not provide evidence that a workable set of procedures were followed.

- Controlled variables that could be identified (or implied) include: size of container, material of container, volume of water in container, initial temperature of water, wrapping of fabrics around containers, location of thermal probe tips in containers.
- "Workable" means "could lead to appropriate conclusion."

Lab Report – Measurement/Data Display

Score	Description
4	Data collected and displayed (or described) in a way that clearly reveals (or would reveal) answer to research question • Data appropriately organized and clearly presented • Narrative or labeling in report makes it clear what the data represent • Sufficient data presented to support a conclusion

3	Data presented (or described) with some lack of clarity in terms of meaning or organization, but can (or could) support conclusion if reader makes some logical inferences about the data.
2	Data, as presented or discussed, is limited or unclear, making a conclusion a "stretch"
1	Report fails to report hard data or data presented (or described) is uninterpretable as presented.

Lab Report – Conclusions/Discussion

Score	Description
4	Report presents an appropriate conclusion about the research question or hypothesis, supported by the research design and data collected, OR the report presents meaningful discussion of difficulties, limitations or possible improvements that, if addressed, would lead to appropriate conclusion.
3	Report presents conclusion reasonably supported by data, but limited relevant discussion, OR report appropriately states conclusion is difficult to draw from the data, but offers discussion of some of the reasons and ways the study could have been improved.
2	Report presents weakly supported conclusion with no discussion OR no or non-supported conclusion with limited relevant discussion.
1	Report presents unsupported or no conclusion and irrelevant or no discussion.

Essay – System Description/Explanation

Score	Description
4	Complete, clear, detailed, appropriately sequenced description of a home heating system
3	Generally accurate description of a home heating system, with unclear or missing step or two
2	Simplistic description of all or most steps in a home heating system
1	Very limited description of home heating system or seriously flawed description

Essay – Understanding of Heat Transfer

Score	Description
4	Accurate and explicit explanation of how at least two methods of heat transfer are involved in home heating system (includes specific mention of names of methods)
3	Accurate explanation of how one method of heat transfer is involved with no or poor explanation of another
2	Mention of method(s) but not clearly tied to particular step(s) in the system
1	No evidence of understanding of any heat transfer method

Essay – Writing Grammar/Mechanics/Conventions (GMC)

Score	Description
4	Demonstrates well-developed command of GMC with few, if any, errors and with fluid sentences and varied sentence structure
3	Demonstrates adequate command of GMC with few errors
2	Demonstrates inconsistent command of GMC with frequent errors
1	Demonstrates poor command of GMC with frequent errors detracting from meaning

Appendix C

Sample Student Work

[to be provided after first use of the CEPA]