DESIGN A METHOD TO CHANGE THE RATE OF **HEAT TRANSFER**

TEACHERS HANDOUT

Utah SEEd Standard 6.2.4
Next Generation Science Standard: MS-PS3-3
Grade and Topic: 6th-grade Integrated Science
Middle School Physical Science

THE UNIVERSITY OF UTAH
College of Education
UTAH FORGE
U.S. Department of Energy

Design a Method to Change the Rate of Heat Transfer

Curriculum developed as a collaboration between the Utah FORGE project and the University of Utah College of Education, supported by the Department of Energy. This curriculum is aligned with national NGSS standards as well as the Utah SEEd standards. The curriculum provides support for diverse learners in diverse environments.

Contents

Overview

Thermal energy and the transfer of thermal energy plays a significant role in all of our lives. At a personal level, these processes are used in heating, cooling, and insulating our homes, in food preparation and safety, in our personal well-being and comfort. At the global scale, these processes are responsible for the Earth's climate and relevant to the current climate crisis. Most power plants, including geothermal plants, operate through the transfer of thermal energy. Enhanced geothermal energy systems are intended to make this transfer of geothermal energy more efficient than is possible through conduction and more widely available than existing geothermal energy systems.

In this lesson, students working in small groups of 3-5, will explore how heat is transferred from hotter to colder objects. From this, the students will design a method to minimize the heat transfer between two objects, present this design to their classmates, and compete in an "ice not melting" contest.

Grade and Topic:

6th-grade Integrated Science

Middle School Physical Science

Standards:

This lesson aligns with the following state and national standards

Utah SEEd Standard 6.2.4 – Design *an object, tool, or process* that minimizes or maximizes heat energy transfer. *Identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the* ***design solution****.* Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)

Next Generation Science Standard: MS-PS3-3. – Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment* does not include calculating the total amount of thermal energy transferred.]

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Overall Objectives for Student Learning:

- Students will make observations about the 3 ways that heat is transferred.
- Students will explore how different materials affect the rate of heat transfer.
- Students will design an engineering solution to reduce the rate of the transfer of thermal energy.

- Students will present their devices to demonstrate their knowledge of thermal energy transfer.

Prior Knowledge:

This lesson would fit into a unit on energy and energy transformations. This could either be an introduction to this unit, a final lesson for the unit, or could fit in the middle of the unit. As an introduction, concepts such as kinetic energy, energy transfer, heat, and temperature, would need to be taught, and explanations involving the kinetic theory of matter would be avoided. (The kinetic theory is that objects are made of particles that are organized and move differently depending on the state of matter). If this lesson occurs after states of matter, students should be reminded of the behaviors of the particles that make up matter and encouraged to use this in constructing their explanations.

Timeline:

This should take approximately five 45-min class periods or 3 90-min block class periods.

Materials:

See each section for the relevant material list

Support for Students with Disabilities:

Students with Disabilities and at-risk learners benefit from specifically designed instruction that gives meaningful access to the general education curriculum (Individuals with Disabilities Education Act (IDEA), 2004). To ensure access to the core curriculum, evidence-based practices, including instructional scaffolding (Kim et al., 2018; Larkin, 2002) and explicit instruction (Archer & Hughes, 2010; Hughes et al., 2017), should be considered when developing lessons to meet individual student's learning needs. This document includes suggestions for teachers to individualize instruction when planning and implementing this lesson plan within each relevant section.

Preparation:

Before beginning

- Read the entire lesson sequence.
- Obtain materials for the Engage, Explore, and Elaborate sections.
- Decide what modifications to make, if any.
- Decide how to organize small class groups (students select their own groups, the teacher assigns groups, the teacher assigns groups with input from students, etc.).
- Decide how to keep the handouts during the lesson, so that the students can refer back to them as needed.
- Decide whether the students will submit the handouts as individuals or as a group.

- Decide the format of the presentations for the Evaluate section.

In the Explain section of the lesson, the students are asked to use consensus-building in order to decide which idea to actually build. If the class has not used consensus-building previously, the teacher should lead a lesson on consensus-building prior to this. We suggest doing this before the lesson, using an innocuous topic, such as what type of cake should the teacher get for a party? or what kind of pet would be the best class pet? etc. The consensus-building activity should be done in small groups, not as a full-class discussion. The students should practice using the talk moves to make arguments and practice active listening.

Day 1

- Prepare slides for the Engage presentation with the anchoring phenomenon and vocabulary words for class discussion.
- Prepare materials for the anchoring phenomenon.
- Prepare instructions, student handouts, and materials for heat transfer stations.
- Set up heat-transfer stations.

Day 2

- Prepare instructions, student handouts, and materials for heat transfer stations.
- Set up heat-transfer stations.

Day 3

- Prepare slides for presentation with the engineering process and applicable web pages.
- Prepare student handouts for the Explain and Elaborate sections.
- Prepare materials for the Elaborate section.

Day 4

- Prepare student handouts for the Elaborate section.
- Prepare materials for the Elaborate section.

Day 5

- Prepare student handouts and materials for the Evaluate section.

Engage: Melting Ice Cube (15 min)

Student Objectives:

Students will make observations about a melting ice cube and propose reasons that explain this phenomenon.

Overview:

In this part of the lesson, the students observe a melting ice cube. Through small group and full class discussions, the students propose reasons to explain why the ice cube melts.

Materials:

Glass of ice water for teacher

Disposable cups, enough for each student

Ice (enough for each student)

Soda, juice, or other beverage (enough for each student)

Student handout – Why does an Ice Cube Melt?

Safety:

Prolonged contact with ice should be avoided.

Introduction: (15 min)

To introduce the concept of heat transfer, the teacher will use the anchoring phenomena of melting ice. The teacher will tell a story about wanting to keep a drink cold, then ask the students to think about what is happening to cause the ice to melt. To engage the students, provide them each with their own drink so that they can observe the ice melting. The physics is that the heat from the environment is being transferred to the ice cube, which increases the motion of the particles in the ice cube such that the ice cube melts. Heat will continue to move from the environment to the ice cube until the temperature of the melted ice cube and the classroom are the same temperature. This is a natural process that results in a more uniform distribution of energy in the system.

Suggested Teacher Script

[Teachers should modify the following story as relevant to their lives and classrooms.]

Good morning everyone. I need your help today. I have decided that I need to start drinking more water, I find that I am dehydrated at the end of the day. So, I have been filling this glass (show glass to the class) with ice water, because I prefer to drink cold water. But, I start teaching, and the next thing I know, all the ice in my glass has melted and the water is room temperature. I don't want to drink room temperature water, so I went and got more ice cubes, but those ones melted as well! What is happening with my ice cubes? Why don't they stay cold?

Great, so our overall goal for this unit is to prevent my ice cubes from melting. First, I am going to give you each your own drink with ice and an option of either water or <beverage>. So that you can observe firsthand how the ice cubes melt.

Solving the problem of how heat works is pretty important. We use this understanding to save energy when heating or cooling our homes, to keep us safe and warm when skiing, ice skating, and snowboarding, to produce electricity to power our homes, and charge our cell phones.

Working in pairs, you are going to make observations of the ice cube, the question you are answering is: What is happening to cause my ice cube to melt? Please draw some pictures or diagrams to illustrate what you think is happening.

[Hand out drinks and student handouts. Give students time to think about and then talk about their ideas regarding the ice cube. Then accept explanations from the students.]

The students will be adding to their explanation after they finish the Explorations, so the teacher may wish to collect the handouts each day, or if the students have a cubby or similar in the classroom, have the students keep their handouts in that. The students will be using their handouts throughout the lesson.

Next, the teacher will lead a full class discussion on why the ice melts. Students might use words like heat, temperature, hot, cold, icy, freezing. If students have recently completed a unit on states of matter, they might bring ideas from that, for example, in solids the pieces jiggle and in liquids they move around more. They might bring up ways to prevent the ice cube from melting. They might talk about energy, energy transfer, movement, flow. During the discussion, the teacher should collect the vocabulary words the students mention and introduce other relevant vocabulary words as needed.

The teacher should highlight ideas that are productive. For example, one productive idea is that heat is being transferred from the air to the ice cube. Another productive idea is that there is a difference between the motion of the molecules of the ice vs. the motion of the molecules in the water. Students may bring up the idea that cold is being transferred; this would be a good segue into the definitions of heat and temperature, maybe discuss absolute zero temperature scales, what does it mean to be "cold" etc.

The teacher should return to the ice cube phenomenon before moving on. Check-in with the students to see if they agree that the ice cube is melting because heat is being transferred or moved from the environment to the ice cube.

Key Terms:

Kinetic Energy -- energy of motion. Anything that is moving has kinetic energy. Kinetic energy depends on the mass of the object, and how fast it's moving.

Thermal Energy -- heat energy, total kinetic energy of all of the particles in an object. Basically, you take all the moving particles, add up their individual energy from their motion, and that gives you the amount of heat.

Temperature -- the average kinetic energy of the particles in an object. This is what we measure with thermometers, and is how we determine if something is hot or cold. This is related to but fundamentally different than heat. Heat is all of the kinetic energy, temperature is the average kinetic energy. It is possible to have high temperature and low heat if the density is low (ex. the air in a hot oven). The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

Energy transfer -- energy, including heat energy, can be transferred from one object to another.

Additional Terms:

Fahrenheit temperature scale -- temperature scale commonly used in the United States, there are 180 degrees between the temperature at which water freezes, 32 degrees F, and the temperature at which water boils, 212 degrees F.

Celsius temperature scale -- temperature scale commonly used in most of the world, there are 100 degrees between the temperature at which water freezes, 0 degrees C, and the temperature at which water boils, 100 degrees C.

Kelvin temperature scale -- temperature scale commonly used in science, has the same increments as the Celsius scale, however, the scale is shifted such that 0 K is absolute zero, and indicates that there is no kinetic energy in the particles, absolute zero cannot be achieved.

Suggestions for Specifically Designed Instruction in Engaging Students in the Lesson

A. Post expectations and directions in a form that is visual, explicit, and easy to access throughout the lesson.
B. Explicitly Teach Content Vocabulary (Kennedy et al., 2017).
    a. Teach and practice vocabulary in context that are included in the lesson plan
    b. Provide a visual reminder (e.g., notebook, word wall, advanced organizer) of unit vocabulary for students to reference throughout the lesson.
    c. Teach no more that 3-5 per week
C. Give explicit instructions for working with a partner.
    a. Define each partner's responsibilities throughout the engage activity.
        i. Define if the partnership will fill out one worksheet together or if each partner should complete their own worksheet.
D. Student response opportunity (worksheet Why Does and Ice Cube Melt).
    a. Consider what kind of response expectation (e.g., written or oral) is the best check for understanding for each student.
    b. Review the expectations for student proficiency. Describe what the expected response is for a student to reach proficiency.
    c. Leave enough white space on the worksheet for students to respond to the questions written or provide an avenue for students to respond to meet the expectation for the assignment.
    d. Review IEP for accommodations and modifications for student response.
E. Students' expectation in discussion
    a. Anticipate the understanding for students with disabilities in heat transfer.
    b. Include the students with disabilities in class discussions that set the students up for opportunities of success.
        i. Asks students to respond to a question while targeting a question that has been reviewed for accuracy prior to discussion.
        ii. Give students advanced warning of a question that teacher poses during discussion. For example, tell the student that you will ask them to share the answer to number 2 on their worksheet.

c. All of the highlighted information in the discussion should be presented to meet the unique learning needs of students.
   i. Provide advanced organizer with cloze procedure to capture important information.
   ii. Provide students a copy of teacher notes.
   iii. Provide student a written or visual copy (e.g. ppt) of information that will be critical for student understanding.
   iv. At minimum, teacher should verbally highlight critical topics in presentation. For example, "This is important, please write it in your notes."

Explore: Heat Transfer (60-75 min)

Student Objectives:

Students will make observations about the 3 ways that heat is transferred.

Students will collect data about materials that allow or prohibit heat transfer.

Students will make inferences about the differences in these materials.

Students will apply these observations to their explanation of the melting ice cube.

Overview:

In this part of the lesson, the students will explore the three ways that heat is transferred as well as how different materials contribute to or prevent that method of heat transfer. Heat can be transferred through conduction, convection, and radiation. Students should spend approximately 15-20 minutes at each station.

Materials:

Student handouts -- Station 1: Observing Conduction, Station 1, cont.: Is it a Conductor? or it is an Insulator?, Station 2: Observing Convection, Station 3: Observing Radiation, Station 3, cont: Changing the Radiation.

Instructions for each station

Additional materials

see the specific station for materials at each station

Safety:

The hot water should be warmer than room temperature, but not so hot as to cause burns. Care should be taken around the hot plate and the heat lamp to avoid burns. Do not touch the hot elements, wait until they have cooled before handling. Prolonged contact with ice should be avoided.

Introduction: (5 min)

Next, the students will explore 3 stations that demonstrate the ways that heat can be transferred: conduction, convection, and radiation. At each station, the students will observe the phenomena, then investigate ways to increase or decrease heat transfer.

Conduction is when heat is transferred through direct contact. The students will touch two beakers: one with ice water, one with hot water. Heat is transferred from the hot beaker to the students' hands, and from the students' hands to the cold beaker. After making these observations, the students will be supplied with assorted materials to test if these materials allow heat to transfer or prevent heat from transferring. The students will be asked to make observations and inferences about the type of objects that conduct heat vs. the types that do not conduct heat.

Convection is when heat is transferred through the motion of fluids. To demonstrate this, the students will place a beaker on a hot plate, turn the hot plate on, and add some glitter to the water. As the water heats from the bottom, the heated water will rise, displacing the water above it, pushing it to the side. This cooler water will move to the bottom of the beaker, establishing a convection cell. The motion of the fluid can be observed through the behavior of the glitter.

Heat is transferred through radiation in the form of infrared radiation. Students will hold their hands near the heat lamp to feel the heat coming off of this object. After observing this phenomenon, the students will investigate how different materials affect how heat is transferred via radiation.

After exploring the stations, the teacher should add the new terms to the slide with the key terms.

Further Key Terms:

Conduction – when heat is transferred by direct contact.

Conductors – materials that allow heat to be transferred through conduction. Most metals are conductors.

Insulators – materials that limit heat transfer through conduction. Many non-metals are insulators. Materials made from non-conductive fibers maximize the insulating properties by using air as an additional insulator.

Convection – when heat is transferred through the movement of fluids.

Fluid – something that can "flow." Liquids like water and gases like air are both fluids.

Radiation – here radiation refers to how heat is transferred through electromagnetic radiation, in particular infrared, IR, radiation.

Suggested Teacher Script

Okay, so we talked about how the heat from the classroom was transferred to the ice cube, causing the ice cube to melt. The next thing I want to do is figure out the ways that heat can be transferred from one object to another.

You will be exploring 3 stations that demonstrate the various ways that heat is transferred.

[Provide instruction on forming groups, safety (care in handling hot objects), and rotating through stations. Check to verify that the students understand the instructions, then allow students to move to the three stations.]

As the students conduct their investigations, the teacher will move through the class, checking on the different groups, asking questions, and highlighting observations. The teacher will notify students when it is time to change stations.

Suggestions for Specifically Designed Instruction in Transition to Stations

A. Explicitly teach and post directions and expectations in a format that is easily accessible for students to access throughout lesson.
    a. Provide emphasis on safety at each station.
    b. Emphasize consequences for non-compliance
    c. Prepare an alternate activity for students who do not follow the safety protocols for the activity.
B. Explain and allow students to practice talk moves prior to working in within their group.
C. Describe and allow students to practice the actions of active listening prior to working in groups.
D. Post and be explicit with time. Use a timer and give a 5-minute warning. Explain procedures if students finish task early or do not complete the tasks at each station.
E. Be clear and consistent on the format of note taking, how work should be to be turned in, and expectations for mastery.
F.

Station 1: Conduction (15-20 min)

Materials:

Station instructions, 2 pages (either laminated or in a sheet protector)

Beaker with ice water

Beaker with hot water (warmer than room temp, not so hot as to cause burns)

Assorted metal objects

  Metal foils can be purchased at art supply/craft stores

  Heat conductivity rods can be purchased from scientific supply companies

  Other metal objects can also be used

Assorted insulating materials

  Pieces of assorted fabric types

Sheets of paper, cardboard, plastic, silicon

Styrofoam, wood, etc.

Other insulating materials

Liquid crystal thermometers (optional)

Safety:

The hot water should be warmer than room temperature, but not so hot as to cause burns. The pieces of metal can be sharp, so discuss safety with sharp objects.

Directions:

To observe conduction, the students place their hands on the hot and cold beaker to feel the direction of heat transfer.

To test how different materials conduct heat, the students apply the object to the outside of the beaker (in the case of the foils and sheets) or dip into the beaker (in the case of the rods or other items) and observe whether or not the temperature of the object changes.

If desired, the students can make quantitative measurements of the heat changes using liquid crystal thermometers.

Additional details are in the student handouts and station instructions.

Troubleshooting:

Check to make sure that the hot beaker is still warm and that the cold beaker is still cold. If needed, refresh the hot water and/or add ice to the cold beaker.

Fabric, paper, and cardboard should only be placed outside the beaker rather than in the water, as the water absorption will change the results. Other items can be observed either outside or inside the beaker.

Station 2: Convection (15-20 min)

Materials:

Station instructions, 1 page (either laminated or in a sheet protector)

Hot plate

Beaker filled with water

Glitter

Safety:

Care should be taken around the hot plate to avoid burns. Do not touch the hot elements, wait until they have cooled before handling. The water should not be heated to the point of boiling.

Directions:

To observe convection: fill the beaker with cool water, place the beaker on the hotplate, turn the hotplate to low, sprinkle glitter in the water.

As the water in the beaker is heated from the bottom, it will begin rising, pushing the water above it to the side, and pulling in the water from the side to form a convection cell. The students should be able to observe the glitter rising and falling as the cells form.

Additional details are in the student handouts and station instructions.

Troubleshooting:

It is unlikely that a single cell will form, rather there may be multiple cells of various sizes. However, the students should be able to see particles of glitter both rising and falling.

Station 3: Radiation (15-20 min)

Materials:

Station instructions, 3 pages (either laminated or in a sheet protector)

Heat lamp or similar

Several beakers filled with cool water

Sheets of assorted materials

Craft paper in several colors, including black and white

Sheets of foil

Thermometers (optional)

Safety:

Care should be taken around the heat lamp to avoid burns. Do not touch the hot elements, wait until they have cooled before handling.

Directions:

To observe radiation, turn the heat lamp on. By holding their hands in front of the heat lamp, students can feel the heat radiating from the lamp. DO NOT TOUCH THE HEAT LAMP.

To observe how different materials affect the rate of absorption of the radiative energy, place the beakers in front of the heat lamp, and place the paper and foil in front of, or behind the beakers (these are measuring different things). As a control, the students should include on beaker without any of the paper/foil sheets.

After a few minutes, feel the temperatures of the different beakers to determine which materials best insulated the water from the radiation vs. which materials increased the absorption rate of the radiation by the water.

If desired, the students can make quantitative measurements of the heat changes using a thermometer.

Additional details are in the student handouts and station instructions.

Troubleshooting:

As the directness of the radiation significantly influences the temperature change, all beakers should be placed directly in front of the heat lamp. This will limit the number of items the students can test at the same time.

As the starting temperature of the water will also affect the final temperature, all beakers should begin at the same temperature, using room temperature water is the simplest way to solve this problem.

If the students choose to do subsequent tests, they should replace the heated water with room temperature water, and make sure to heat the water for the same amount of time as they did on the previous test.

Suggestions for Specifically Designed Instruction In Small Groups

A. Allow students to see the questions to be answered prior to starting the station.
B. Give the students with disabilities the reading prior to the activity.
C. Highlight main ideas and important information in the text prior to the station activity.
D. Provide graphic or advanced organizers to scaffold student learning and classify information.
E. Provide an advanced organizer using a cloze procedure to note important information and main ideas.
F. Reduce cognitive demand by assigning students to gather specific information rather than all information simultaneously.
G. Teach and practice the expectations when working in a group at each station.
    a. Consider if is student should touch the beakers with each different material.
        i. If so, be very clear on time to touch each object; what kind of response is expected with each object; and kind of response is expected.
        ii. If not, provide an explanation of what information should be shared after each trial of materials. Teacher may provide a sentence starter or guideline for response.
H. Consider assigning students with disabilities a consistent role throughout the rotations
I. Follow all accommodations and modifications listed on the IEP.

Integration: (5-10 min)

Finally, the teacher will ask the students to add the three types of heat transfer to the explanations that they created earlier. The teacher will instruct the students to look again at their earlier drawings to explain why the ice cube was melting and add to their drawing the places where the ice cube is being heated by each process. The teacher should give the students a few minutes to add this to their explanations.

The teacher should add the new key terms to the slide or poster of key terms from the Engage section of the lesson.

Explain: Design a Device (30 min)

Student Objectives:

Students will identify the steps in the engineering process.

Students will use their investigations on how different materials affect heat transfer to brainstorm ways to minimize heat transfer.

Overview:

The Explain and Elaborate parts of this lesson are embedded in the engineering process. In the engineering stage of this lesson, the Utah SEEd Standard states that the students will design an object, tool, or process to either maximize or minimize heat transfer. As the motivating phenomenon of this lesson is to prevent an ice cube from melting, this lesson is written to minimize heat transfer. However, teachers can modify this to fit the needs of their classroom.

As with the "scientific method," the actual process of engineering is much more complicated and intricately interwoven than the steps listed in most textbooks. However, in the same way as the scientific method in a textbook has clear steps to help students navigate the process, there are steps that most engineers agree are essential parts of the process.

Here, we break the engineering process into the following seven steps:

1. Define the problem -- to design an engineering solution, there needs to be a well-defined problem. The well-defined problem in this lesson is already provided, **How can we prevent the ice cubes from melting?**
2. Identify criteria and constraints -- there will always be criteria and constraints. The criteria are usually that the design solution is better/cheaper/faster at solving the problem than the current method. The constraints are often financial, but may also be societal. In this lesson, the criteria are that the design needs to **minimize the transfer of thermal energy to the ice cube to prevent it from melting**. The teacher may want to include additional criteria. The constraint is that the students need to construct the object, tool, or process **using materials available in the classroom or by recycling other materials from home or the school**. The teacher may wish to include additional constraints.

3. Research the problem -- there are many things that need to be researched when working on an engineering design solution. Often engineers will both investigate what solutions others have already created and determine if there is a demand for a new solution. Here the students have begun to investigate **what materials will work best to prevent heat transfer**. The teacher could also require the students to investigate how others have solved this problem.
4. Develop possible solutions -- before building a final project, engineers will draw schematics and make prototypes. This usually involves brainstorming ideas. In this lesson, the students will **build a prototype of their object, tool, or process**.
5. Analyze data from iteratively testing -- this is the heart of engineering, trying and trying and trying again. Here the students will **iteratively test the effectiveness of their "ice cube melting prevention method," and make changes to the prototype,** to improve the method. When engaging in this step of the lesson, encourage students to make systematic changes to their design, record every change made, and collect data on how the method performed after each change in order to determine which iteration was most successful.
6. Optimize the design solution -- once the students have completed their iterative testing, and taken excellent notes on their process, it should be fairly straightforward to **pick the optimal method to prevent the ice cube from melting**. However, often there are conflicting optimizations, for example, we might be both trying to reduce the cost and decrease the heat transfer. Unfortunately, the better insulators cost more. The optimal solution must make a judgment call on which of these conflicting needs to optimize.
7. Communicate the results -- essential to both engineering and science. If you don't communicate your results, your solution is meaningless. In this lesson, students will **compete to see whose ice cube takes the longest to melt**.

In this step of the lesson, the teacher will lead the students in a discussion to introduce the engineering stages of the lesson. The students will then begin the engineering process working in their small groups from before.

Materials:

Computer with internet access

Projector

The Engineering Design Process: A Taco Party (~5 min)

https://www.youtube.com/watch?v=MAhpfFt_mWM

Student handout – Beginning the Engineering Process: Designing a Method to Reduce Heat Transfer

Introduction: (5 min)

Here the teacher will introduce the engineering process by showing a short video that explains the steps of the process. The steps in the recommended video are slightly different than the 7 steps described above. There are many other videos available online that go through the engineering process using different steps, however, the recommended video, Engineering a Taco Party, is very straightforward and the steps mostly match the steps in this lesson.

The teacher will introduce the video by reminding the students that the goal for this unit is to design a method to prevent ice cubes from melting. In order to do this, the students will use the engineering process.

The teacher will show the video to the students.

Explanation: (10-15 min)

After the students watch the video, the teacher will lead a full class discussion about the engineering process. For consistency, the steps in the video are added to the list below. When discussing each of these steps, ask the students for ideas on how these steps will be used in the “ice cube not-melter” project.

1. Define the problem.
2. Identify criteria and constraints.
3. Research the problem (not explicitly in the video, implied in the “identify criteria” step).
4. Develop possible solutions
    a. Brainstorm ideas
    b. Select the best idea
    c. Build a prototype
5. Analyze data to make improvements from iteratively testing solutions.
6. Optimize a solution (also not explicitly in the video, implied in the iterative step).
7. Communicate the results.

These steps can be written on the whiteboard or a poster or slide posted on the LMS to refer to during the lesson. In addition to identifying the steps, the teacher will explain how these steps will be used in this lesson, but also encourage the students to think about how these steps would be used in general.

Suggested teacher script:

So, let’s talk about this. Can anyone tell me about a time when you have used the engineering process? Maybe you didn’t know you were using the engineering process, but you did something like this? You had a problem, and you needed to try several things before you came up with a workable solution?

[Accept stories from the students.]

Those are great examples! I love how you are thinking.

[Show slide with the steps written on it.]

1. The first step in the engineering process is to define the problem. Here the problem is: How can we prevent our ice cubes from melting? Who can think of another problem that you could solve with engineering?

[Accept examples of problems from the students.]

2. The second step is to identify criteria and constraints. The criteria are "what does this solution need to do." In this lesson, whatever you come up with needs to keep the ice cube from melting. The constraints are the limits to your solution. In this lesson, you must be able to construct the device using materials that we have in the classroom or that we can recycle from home or the school.

[The teacher may wish to add additional criteria or constraints.]

3. This step wasn't listed in the video we watched but it was hinted at. To solve a problem we want to research it. We might want to research what other people have done to solve this problem, we might want to research if there is a demand for the product we are making. In this class, we already did some research on which materials will work best. You might want to do some further research on the materials we have to select the ones that you will use in your design. [If desired, the teacher may instruct the students to also research other solutions.]
4. Next, we want to start working on developing possible solutions. So, there are a few steps we need to do here:
    a. First, you are going to brainstorm ideas.
    b. Next, you are going to select the idea you think is best.
    c. Finally, you are going to build a prototype of your design.

[Check for understanding.]

5. Now that you have a prototype, you are going to test it to see how well it works. Then you are going to make some changes and test it again. Then you are going to make some changes and test it again. In the video, they called this part iteration. This means repeating the same thing over and over again, making small changes each time. This is a really important step in engineering.
6. After several iterations, you should be able to tell which prototype was the best! So, build that one.
7. Finally, you communicate results. To do that, we are going to have a competition to see which group can keep my ice cubes from melting the longest! You will also need to tell us about your method and how it works. So keep that in mind.

Alright, that is a lot. But, good news! we've already done the first three steps: we defined the problem, I told you the criteria and constraints and you've done some research on the problem.

So, now I want you to get into your groups and use the information you have on how the different materials allow heat transfer to brainstorm some ideas for how you are going to prevent the ice cubes from melting. You are going to need to agree as a group on the method you are going to try.

Once you have decided as a group what you are going to do, you need to get my approval before you start building your prototype. After you have approval you can begin building, testing, and making iterative changes to your prototype. We will be spending [a couple of days, the rest of the class period] on this.

[Check to verify that the students understand the assignment. Once the students understand the requirements they can begin working in their small groups.]

Suggestions for Specifically Designed Instruction for Engineering Process

A. Using a task analysis in the steps of the engineering process and evidence-based practice with positive effect size in the literature (Hattie, 2009). The analysis in the lesson plan is explicit, the teacher should ensure that instruction clearly follows the task as written.
B. Explicitly teach and review specific content and engineering process strategy.
C. Provide advanced organizer for students to take notes. Include the following in advanced organizer:
    a. Seven steps of the engineering process
    b. Visual model or visual organizer of the engineering process
    c. Cloze procedure note taking strategy.
D. Provide students with higher needs a completed copy of teacher notes to decrease cognitive load.
E. Explicitly align you tube video, A Taco Party, to the steps in the engineering process.
    a. The teacher should be clear with the differences in the video process and the classroom practice.
F. Provide examples and non-examples of the engineering process. Non-examples should be anticipated student misconceptions of the process.
G. Check student notes for accuracy and understanding. Use the error correction strategy to clarify misunderstanding.
H. Pre-teach strategy when possible by working with the special education staff and MTSS strategies for pre-teaching.
I. Using the teacher script, praise statements should be specific to the student response as it is aligned to the task and content.

Small-Group Exploration: (10-15 min)

After the teacher has checked that the students understand their requirements, they will work in their small groups to:

- Answer questions about the heat properties of the available materials.
- Brainstorm ideas for their "anti-ice-melting" design.
- Agree on one design
- Obtain approval from the teacher to build the prototype.

While the students are working on this, the teacher will walk around the class checking on the students' progress. The teacher will want to check that the students are brainstorming ideas that can be used to reduce heat transfer from the environment to the ice cubes.

Once the students have brainstormed ideas, the students need to agree on a design before building the prototype. The teacher might want to lead a discussion on how to navigate this process.

- Each student should have the opportunity to present their preferred design and argue why this is the best idea.
- Talk moves are provided to help students navigate this process.
- After each student has presented their case, the group votes using consensus voting: Students signal their vote with their thumbs.
    - Thumbs-up indicates "yes, I want to do that!"
    - Thumbs-down indicates "absolutely not! I will never do that!"
    - Thumbs-sideways is "I'm not enthusiastic about that, can we talk about my concerns?"
- If a vote has any thumbs-down or thumbs-sideways, the discussion must continue with students presenting their arguments.
- The process continues until there is consensus.

Once the students have agreed on a design, the teacher can sign off on the design, and provide the students with materials to build their prototype, which they will do in the Elaborate section.

Suggestions for Small Group Exploration Activity

A. Provide an advanced organizer with questions that outline group discussion.
B. Explain the role each student should take during the small group activity.
C. Provide a think-aloud model of group participation.
D. Model the expectations of the brainstorming activity.

Elaborate: Building a Device (45-60 min)

Student Objective:

Students will build their design solution by building a prototype and iteratively testing the prototype, before selecting the optimal solution.

Overview:

The elaborate part of the lesson completes the next steps of the engineering process: construct a prototype, analyze data to make improvements from iteratively testing solutions, and select the best solution.

This part of the process is largely student-driven, the teacher will support the students by approving the designs before the students start building prototypes, by providing resources to build prototypes, by brainstorming changes that can be made as part of the iterative testing process, by requiring the students keep notes on what changes they made and the results of these variations, and by providing insight into which iteration is optimal. However, the actual solutions being designed and tested will be varied.

Materials:

Ice cubes for testing

Heat lamp or similar for testing

Scale (optional)

Materials from the Explore section of the lesson: sheets of paper, fabric, foil, etc to build the insulating parts

Additional building materials as available, ex. cardboard, tape, glue, etc. to build the structure

Student handout – Continuing the Engineering Process: Building and Iteratively Testing a Method to Reduce Heat Transfer

Explanation/Integration: (45-60 min)

As the students are already working, it is best for the teacher to give instructions on the next steps in the small groups.

1. Iteration 1
   - Build the approved prototype
   - Test this design
   - Record results
2. Iteration 2
   - Modify prototype
   - Record modification
   - Test design
   - Record results
3. Iteration 3
   - Modify prototype
   - Record modification
   - Test design
   - Record results

The teacher may wish to require additional iterations. Once the students have completed the required number of iterations, the students should select the best prototype to build a final design which the group will present to the class.

While the students are working on this, the teacher will walk around the class checking on the students' progress, providing support for the students as needed.

Suggestions for Specifically Designed Instruction for Building a Device

A. State and post expectations for making a prototype.
B. Provide task analysis for completing prototype project.
C. Consider using partner or small groups to complete project.
D. Provide examples and non-examples.
E. Provide stop and check for accuracy throughout the project.

F. Use correction strategy to facilitate misconceptions.
G. Use scaffolding techniques to meet individual learning needs.
H. Provide models and guided practice with a gradual release of learning to the student.
I. Provide a checklist to be completed of each task in the preparation process.
J. Follow all accommodations and modifications listed on the IEP.

Evaluate: Testing the Devices (45-60 min)

Student Objectives:

Students will demonstrate their knowledge of minimizing heat transfer by presenting their designs to the class as part of an "ice cube not melting" competition.

Overview:

The final step of the lesson is to ask the students to share their design for the "anti-ice-melting" object, explain what each part does, then complete to see which design is best.

Materials:

Ice cubes (these should be as close to the same mass as possible)

Scale (optional)

Poster paper and markers or Computers and presentation software

Treats for the full class as awards for the competition

Student Handout – Completing the Engineering Process: Communicating your Results

Introduction: (5 min)

The teacher will introduce the next part of the lesson by giving instructions for what the students need to do next. The students will create a poster or computer presentation of their design that describes how the different parts reduce the transfer of heat (ex. the aluminum foil prevents heat flow from radiation by reflecting the radiation instead of absorbing it, the polyfill fluff prevents the transfer of heat by conduction because it is a good insulator, and by convection by preventing airflow).

Suggested teacher script:

I've been looking at the designs you have created, and I want you to know that I think they are awesome, and I am excited to find out which one works the best! But before we can test them, we need to be able to explain to each other what we did, and why we did it. So I am going to give you about 20 min, to make a [poster, presentation] that shows your design, and also explains how each part of it works. So, for example, if I used aluminum foil in my design, I probably used it to prevent heat transfer from radiation cuz it reflects radiation instead of absorbing it. I hope I didn't use it to prevent conduction, because aluminum is a pretty good conductor, and that would make my ice melt faster, not slower!

After you make your presentations, we will test the designs to see how well they work. But, while we are waiting for the ice to melt, we can show off our designs to each other, by [setting up the posters around the room, hanging them on the wall, showing our presentations on our laptops, etc.]

[Check to verify that the students understand the assignment. Once the students understand the requirements they can begin working on their presentations.]

Explanation: (20-25 min)

The teacher will provide the students with the materials and presentation instructions. While the students are working on their posters/presentations, the teacher will check on the groups to make sure they are including diagrams of their designs as well as explanations that address each of the three ways that heat is transferred. If students are struggling, remind them to look at their work from earlier regarding which materials conduct heat and which ones do not. Ask the students to provide explanations for why the material is good at preventing heat flow (the material is fluffy, the material is not made out of metal, the material is reflective, the material is white, etc.)

Evaluation: (20-30 min)

Once all groups have finished their presentations, the ice cube testing can begin. The teacher will provide each group with one ice cube, and have the students place the ice cube in their device. The students will then place all devices in the same section of the classroom, such that the devices all experience the same ambient temperature.

While waiting for the ice cubes to melt, the students will share their posters or presentations with the class in a "science fair" format. Here each group stands near their poster/computer to show their design to their classmates. The teacher will give instructions on how the students will visit each other's presentations (ex. Have the students count off, and odd-numbered students stay at their posters while even-numbered students visit the other posters then switch after 10 min.)

After the presentations, the teacher will check each ice cube to see which one has melted the least. The teacher can use a scale to determine the total amount of ice remaining for each group if desired. The teacher can then give treats or other rewards to the students for their hard work in designing their devices.

Suggestions for Specifically Designed Instruction during the evaluation and presentation

A. Preparation for presentation
    a. Create an advanced organizer with script that includes:
        i. The information that must be present in the poster or presentation

1. The design of the prototype
2. Explanation of how the prototype works
3. Explanation of how each part of the prototype works

b. A script that explains the process and results the student prototype
c. List of anticipated questions and responses during presentation
d. Check for understanding throughout process

B. Explanation
    a. Allow student to practice the presentation prior to presenting in class.
    b. Provide examples and non-examples
    c. Scaffold instruction throughout process
C. Provide clear grading requirements prior to preparation and presentation of proposal.
D. Explicitly teach and model expectations when being an audience member during peer presentations.
E. Follow all accommodations and modifications listed on the IEP.

Suggestions for Specifically Designed Instruction for evaluation

A. Follow grading expectations and give feedback for grading procedures.
B. Consider alternate forms of presentation (e.g., just to teacher, record in private and submit, oral presentation only, visual demonstration only).
C. Evaluate only learning objectives of the lesson (e.g. reading, spelling, and quality of presentation skills are not a learning target in this lesson).
D. Consider holistic scoring.
E. Follow all guidelines in the student's IEP.

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