How can we prevent a chocolate bar from melting in the sun?

Primary: (ages 7-11)	**Subject: Science (Earth Science, Physical Science)**

In this unit, students investigate weather, heating, cooling of materials, and the effects of sunlight and shade. They engineer a design solution to prevent a chocolate bar from melting in the warmth of sunlight. They consider the benefits and drawbacks of human-made technology versus natural solutions.

Time allocation	About 12 lesson periods
Subject content	Changes of state, heat transfer, conduction, convection, properties of materials, weather vocabulary, observe and record weather data, light and energy from the sun, cloud formations
Creativity and critical thinking	This unit has a **creativity** and **critical thinking** focus: • Students evaluate and compare natural solutions and human-made technology for mitigating the effects of sunlight on objects. • Students engineer a novel solution to a problem related to protecting an object from warming.
Other skills	Collaboration, Communication
Key words	Weather, melting, engineering, model, nature-made and human made materials, drought, sunlight, climate

Products and processes to assess

Throughout the lessons, students ask questions about what they see, develop beginning understandings of energy, and locate the sun as the source of heat outside. Students are developing initial explanations based on evidence from observations and qualitative and measurement data. They design and present solutions that build on other human-made and nature-made solutions to insulation. At the highest levels, students develop a personally novel solution that insulates the chocolate from heat, they select materials with sound reasoning, and they can explain their solution, why they feel it is novel, and the choices they have made and rejected to others.

Authors: Miller, E., Severson, A., Codere (2021) for the OECD for the CERI project *Fostering and assessing creativity and critical thinking skills*, edited by Cassie Hague (Analyst, OECD).

Teaching and Learning plan

This plan suggests potential steps for implementing the activity. Teachers can introduce as many modifications as they see fit to adapt the activity to their teaching context.

Step	Duration	Teacher and student roles	Subject content	Creativity	Critical thinking
	(Preparatory phase)	Ask students if they know how to describe the weather. Collect ideas for describing it and have students write ideas down. Go outside on multiple occasions and ask students to gather data of the weather. Ask how they think they can best record what they are seeing about the weather E.g., if it's a cloudy day – how can you use words, pictures, numbers and graphs to explain different levels and degrees of cloudy? Introduce names of clouds, like cirrus, cumulus and cumulonimbus. Explain that clouds are water droplets, dust and bacteria. If it's windy, help students think of ways to measure windy and wind direction (i.e., a windsock or flag). If it is a hot day, how could you measure and record levels of hot? Ask how they could all go outside and agree on the amount of hot it is. When students get stuck, make suggestions as appropriate. Ask students if they can think of any sayings about weather (such as 'red sky at night, sailors' delight'). Discuss whether these are generally accepted by people, why people think they might be true or untrue, and how they can be tested through recording and observation. When back in the classroom, discuss with the class the differences between using words, pictures and graphs to represent and communicate about the weather. What sort of information is useful for different purposes and audiences? Check with students what they feel they know about the weather what they are still uncertain about (either in writing or orally).	Weather: describe weather, measure weather, graph weather patterns, cloud formations, and weather-related vocabulary.	Inquiring: Observe, describe and make connections between different aspects of weather and with methods of measurement and representation.	Inquiring: Understand the context, identify and question generally accepted ideas, check accuracy, and analyse gaps in knowledge regarding an everyday familiar phenomenon, the weather.
1	Lesson periods 1 and 2	Explain to students that they will have a treat after playing outside and show them the chocolate bar (make sure it is a sunny day!). Place the chocolate bar in the sun whilst the students are at lunch or recess. Gather the students together to share the treat, notice with surprise that it is melted. (You might want to give them another different treat).	States of matter; changes of state; properties of materials; what	Inquiring: Observe, describe and make connections between relevant	Imagining: Consider several perspectives on the problem of how to prevent an object from melting.

Ask for volunteers to explain what happened to the chocolate bar, asking them questions such as what form was the chocolate in before and after it melted? Explain that matter on Earth exists in one of three main states: solid, liquid, or gas. Explain that when you add energy (heat) to some things (e.g. ice cream), it causes melting and ask students to think of other things that melt when they are heated or share times when they have seen other things melting, prompting them to think and record how long the process might take and what sort of temperatures would be needed. Introduce the Driving Question (DQ) (**how can we prevent a chocolate bar from melting in the sun**), starting a DQ board (an accessible and visible area where students can record and arrange their ideas and questions related to the driving question). Have students break into groups and write down as many initial ideas as they can about how they could stop the chocolate bar from melting, what extra information they need to find a solution, and any questions they have. Students can draw inspiration from the experiences (of melting/ changes of state) shared earlier. Lead a process of organising ideas and questions into categories, asking for student suggestions (for example they might have ideas for ways to protect the bar from the sun. They might have ideas for ways to cool it. They might have questions they think someone could answer (How hot was it today?), questions that they could find out through investigation (How hot does it have to be to melt chocolate?), as well as questions that there could be disagreements about (Does melted chocolate still taste good?) When there are differences of opinion about where an idea should go, ask students to try to convince others that the question or idea belongs in a specific category. Ask students to notice if they change their mind and why. Have students write their questions and ideas on the DQ board	causes materials to melt.	experiences of physical change. Imagining: generate as many ideas as possible about preventing an object from melting. .

2	Lesson periods 3 and 4	Remind students of the driving question. Tell them they will be going outdoors and using their sense of touch to feel the temperatures of different objects and Earth surfaces (pavement, grass etc.). Before leaving, ask students what they would like to touch (challenge them to think of some unusual places and have ideas of your own, too). Challenge students to make predictions about which objects/Earth surfaces they think will be hot or cold and why. Outdoor Observations: Take students outdoors and have them collect data about the relative temperatures of various objects and Earth surfaces on sticky notes. They will be using their sense of touch and qualitative words. They can also use a thermometer, as appropriate. They will use their data to make comparisons later in the lesson. Make sure they experience some temperatures at both ends of the continuum (hot to cold). Be careful not to have students touch very cold or very hot objects. Analyse the data: When students return to the classroom, display the data they collected. The sticky notes have words and pictures on them that capture objects/surfaces felt and the qualitative words used to describe their temperatures. Ask students to compare the objects and Earth surfaces. You could use a sentence frame such as: _____ is warmer or cooler than _____. Make claims and provide evidence: Invite the class or small groups of students to discuss *why* they think the temperatures of the objects/surfaces were different. They might talk about the size or color of the object or what it is made of. If no one brings up sunlight or shade (the lack of sunlight), offer it as an idea for them to consider. Provide them with basic facts about heat transfer (e.g. conduction, convection, radiation and how each can be reduced), as appropriate to local context and student level. It may be useful to provide students with a list of relevant vocabulary and definitions that they can refer back to throughout the unit. Ask students in pairs to make a model/s of an object/Earth surface they observed that explains why it was hot or cold. Invite a few students to share their models and then have students reflect (either in writing or	Gather data, using thermometers. Compare and contrast temperatures of objects. Heat transfer.	Reflecting: reflect on their choices and models, relative to possible alternatives and acknowledge remaining uncertainties.

		verbally) a) on their own models relative to possible alternatives and b) on the lesson so far, and any uncertainties they still have. Add ideas and questions to the DQ board.			
3	Lesson period 5, 6 and 7	Revisit the DQ board. Ask a few more students to share the models about temperatures of objects/Earth surfaces they made. This will help students remember what they learned about in the previous lesson. Collect additional questions, if there are any. Tell students that today they will plan and carry out an investigation to find out what effect sunlight has on different materials found on Earth's surface. Planning Investigation: In pairs, students talk about and/or examine Earth materials they will investigate (sand, soil, rocks, water, pavement, etc.). Remind students they are trying to find out how sunlight affects these different materials found on Earth's surface. Remind them that they will need to know what happens in the sunlight and what happens when there isn't sunlight (there's shade) shining on the material. Ask them to talk with their partners about different ways they might go about doing this. Invite pairs to share ideas with the class. Are the ideas similar or are some more unusual and why? What are the limits of the suggested ideas? How can we select an idea to try? Conduct the investigation (Must be a sunny day!): Have students carry out the investigation as a whole group or in small groups, if possible. Students should prepare two equal-sized samples of each Earth materials — one they will place in full sunlight and one they will place in the shade. Let the samples sit out for at least 30 minutes to an hour and come back to collect data. Gather, represent, and analyse data: Ask groups to use pictures, words, and real temperatures (if students can use thermometers). Have them identify patterns of the relative warmth of materials left in sunlight and materials left in the shade. Ask students for their ideas on how to represent the data in some visible way. Revising models: Have students return to the models they made in the previous step and ask them to add to them to show either the effect of sunlight or of shade on the temperature of their object/surface. They will need to apply what they learned.	Planning and conducting an investigation. The effects of sunlight on surface materials. Identifying patterns, presenting ideas with a model. Radiation.	Imagining: Generate and explore ideas regarding how to collect evidence for an investigation. Doing: Pose and propose how to explain data and model an explanation in a personally novel way.	Reflecting: on chosen solution relative to possible alternatives to revise models.

		Wrap up: Ask one or two volunteers to share and explain their revised models (prompting them to use terms such as absorb, radiation, heat transfer etc. as appropriate). Ask remaining students to comment on similarities and differences between the models and, if relevant, what is novel about each. Ask students if any of the learning they did in the lesson can help answer one of the questions on the DQ board. Also ask for any more questions that came up during the lesson.			
4	Lesson period 8	Begin with the DQ board. Revisit questions and ask students if any have been answered or if they would like to add more. Ask a few more students to share their revised models from the previous lesson with the whole group. Review the effect that sunlight had on the Earth materials used in the investigation. Analyzing data from Investigation: As a class, review the data collected during the investigation in the previous lesson and any patterns that were identified. Ask if students notice anything new. Making a claim: Invite students to talk in pairs and make a claim — a statement they believe to be true from the evidence they have collected — about the effect that sunlight has on Earth's surface. As appropriate, encourage students to use the scientific vocabulary they have learned in previous lesson periods in their claims (students can refer to their vocabulary list). Have pairs share their claims with the rest of the class to gain feedback and refine them. Prompt the class to notice any differing perspectives. Constructing explanations: Choose one claim and work together as a class to select evidence that supports it. Look back at the vocabulary and data representations made during the past lessons. Ask if anyone has had any experiences or evidence that could be used as additional reasoning to build a solid argument to support the claim. If there is time, students could work on adding evidence to other claims in pairs or small groups. You could also choose to construct another explanation together as a class. Ask students, if their explanation can apply to other objects and why/why not.	The effect of sunlight, using evidence to develop explanations using scientific vocabulary.	Imagining: Explore, seek, generate ideas regarding how to draw a picture (a model) of the effect sunlight can have on objects.	Doing: Explain both strengths and limitations of claims about the effect of sunlight based on available evidence.

		Go back to the questions on the DQB. Check to see if any more questions can be answered. Ask students to go home and talk to their family and care-givers about how they might keep a chocolate bar from melting, including human-made and nature-made solutions. (Note: Nature made could be something that occurs in nature such as the shade of the tree, or underground solution, as well as an adaptation an animal has for staying cool (such as the reflective fur of the fennec fox).			
5	Lesson period 8 and 9	Revisit the unit and remaining questions. Remind students that sunlight warms objects and Earth surfaces and explain that students will now use what they have learned about this and their previous thinking to design a solution to stop chocolate from melting. Introduce the materials students will be able to use in their designs. (Note: You may add to or change the materials according to your needs). 1. Discussing ideas and making models: Give students 15 minutes to discuss ideas in pairs or small groups about how to use the provided materials to make a design solution that will keep their chocolate bars from melting. Invite them to explore the materials and to consider several possibilities for how they could solve this problem. 2. Ask students to select the design they want to implement and why (the teacher can make suggestions about appropriate criteria if needed) and make models of their plans — e.g. what structure they will design or which materials they will use to protect their candy bars from the warmth of sunlight and why. 3. Providing input: Students explain and justify how their planned structures will protect their candy bars from the sun and get feedback from other students and from you. They then have time to revise their plans and models to overcome any constraints. Wrap up: Encourage students to share their ideas with their families and get additional feedback before building their structures during the next lesson.	Applying knowledge of properties of materials, effect of the sun, and weather patterns to solve the problem of how to prevent chocolate from melting.	Doing: Design a meaningful and personal novel solution, generate ways to meet criteria and overcome constraints.	Doing: Justify a solution based on reasoning about its strengths and limitations.
6	Lesson periods 10 and 11	Remind students about the design challenge you posed in the previous lesson and the models of their structures. Ask if students got ideas and feedback from their family members about their plans and models. Let partners meet together for a few minutes to discuss feedback they	Constructing engineering solutions based on criteria (what it needs to do) and	Doing: Design and implement personally novel solutions to	Reflecting: Reflect on the chosen scientific solution and consider possible

		received and changes, if any, they'd like to make and why. Restate that the goal is preventing their chocolate bars from melting in the sun. Building the structures: Students build their structures (or implement other solutions) using only the provided materials and tools. Conducting the investigation: Take students outdoors and have them place their structures in the sunlight. The chocolate candy bars should be placed on trays inside of structures. Evaluating the solutions: Students will collect data on all the solutions. They will observe how much, if any, melting occurs. They could check at specified time intervals, if desired. Otherwise, wait until one hour has passed and then pose questions such as, "Which design structure does the best job of preventing a chocolate candy bar from melting? How do you know? Why do you think it works?" Have students discuss criteria for what makes a "good" or "best" solution, and introduce and explain terms like insulators, absorbed, reflected etc. as appropriate. 1. Wrap Up: Invite a few volunteers to describe the results of their attempts to prevent melting — How well did their designs work and why? 2. Ask students to provide an example of a solution that is nature made or influenced and one that is human made. Ask students to consider benefits and drawbacks of each one.	constraints (available materials); insulators	prevent heating of an object	alternatives that use different choices of design and materials.
7	Lesson period 12	Discuss with students whether their solutions could be used on a larger scale to keep things cool whilst using less energy and why/why not (this discussion can be linked to climate change if the teacher wishes). Have a "cool" family and community fair, where students present their engineered solutions, explaining why they work using the knowledge and vocabulary they have developed in the unit. Some students may make changes to their design. Share a "cool" drink with everyone. Have each student consider how their designs are similar are different from one another, and from items used in people's daily lives and well as cooling solutions in nature. Have students continue to identify materials in their homes, and in nature that can keep things cool. Finish by asking students to reflect (either in writing or orally) on the steps they took and why, what they felt was novel about their work, and what they learned.	Communicating why their solutions work using scientific knowledge and vocabulary	Reflecting: Reflect on steps taken and revise solutions based on outcomes.	Reflecting: Evaluate and acknowledge the uncertainty or limits or the solution.

Resources and examples for inspiration

Web and print

- cloud classification

Other

- Notebooks or loose paper and writing tools; Cups or bowls (for ice cubes)
- Paper towels (to clean up messes)
- Sticky notes and dark marker
- Thermometers
- Whiteboard and markers/chalkboard and chalk (to record melting methods)
- Chocolate candy bars (1 for every 2-3 students)
- Possible materials for building structures
    - construction paper of varying colors
    - tongue depressors
    - pipe cleaners
    - aluminum foil
    - cheese cloth
    - large pieces of felt
    - tray for candy bar (pulp or Styrofoam)
    - other materials you would like your students to have available

Opportunities to adapt, extend, and enrich

- This could be extended by asking students to read and write stories that feature weather, melting, and changes of state, for example, using *The Snowy Day* by Ezra Jack Keats or *The Snowman* by Raymond Briggs
- This mini-unit is based on portions of the two learning sets in a sequence of five learning sets. Remaining learning sets have students engage with texts about weather, and study weather patterns including extreme weather in the area.
- Remaining learning sets, along with additional STEM project-learning units and related resources can be found at https://sprocket.lucasedresearch.org//. ML-PBL Units were co-developed by the Multiple Literacies in Project-based Learning Project at Michigan State University and the University of Michigan 2018–2020. ML-PBL units are licensed under a Creative Commons Attribution-NonCommercial 4.0 International License and funded by the George Lucas Educational Foundation.

Creativity and critical thinking rubric for science

Mapping of the different steps of the lesson plan against the OECD rubric to identify the creative and/or critical thinking skills the different parts of the lesson aim to develop

	CREATIVITY Coming up with new ideas and solutions	Steps	CRITICAL THINKING Questioning and evaluating ideas and solutions	Steps
INQUIRING	Make connections to other scientific concepts or conceptual ideas in other disciplines	Prep, 1	Identify and question assumptions and generally accepted ideas of a scientific explanation or approach to a problem	Prep
IMAGINING	Generate and play with unusual and radical ideas when approaching or solving a scientific problem	3, 4	Consider several perspectives on a scientific problem	1
DOING	Pose and propose how to solve a scientific problem in a personally novel way	3, 5, 6	Explain both strengths and limitations of a scientific solution based on logical and possibly other criteria (practical, ethical, etc.)	4, 5
REFLECTING	Reflect on steps taken to pose and solve a scientific problem	7	Reflect on the chosen scientific approach or solution relative to possible alternatives	2, 3, 6, 7