BIG BEAR VALLEY
EDUCATION
TRUST

BEARTECH
Embrace Your Place

Snow-making Unit

5th Grade

NGSS Aligned Snow-making Unit

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California NGSS and 5E Instructional Model Overview

This unit aligns with the three dimensional CA Next Generation Science Standards (NGSS):

1. **Crosscutting Concept (CC)**
2. **Disciplinary Core Ideas (DCI)**
3. **Science and Engineering Practices (SEP)**

The unit also aligns with the mission of the Big Bear Valley Education Trust: To create **interactive and engaging educational opportunities to foster environmental stewardship** and lifelong learning for students, community members, and visitors, **using the unique resources of Big Bear Valley.**
The lessons are written using a 5E (Engage, Explore, Explain, Elaborate, and Evaluate) format as recommended by the NGSS. According to the NGSS, "It is important to avoid front-loading and to instead allow students to develop an understanding through engagement and exploration. These experiences allow students to understand the concept, even define it, before a term is presented. This gives the students the opportunity to 'discover' the concepts on their own and something to connect the terms to. Students can then elaborate, or apply, the new concepts to related phenomena for a deeper understanding."
(http://nextgenerationscience.weebly.com/5-es-of-science-instruction.html)

"The BSCS 5E Instructional Model is/does the following:

- The five phases of the BSCS 5E Instructional Model are designed to facilitate the process of conceptual change.
- The use of this model brings coherence to different teaching strategies, provides connections among educational activities, and helps science teachers make decisions about interactions with students.
- Each phase of the model and a short phrase to indicate its purpose from a student perspective are:
    - Engagement - students' prior knowledge accessed and interest engaged in the phenomenon
    - Exploration - students participate in an activity that facilitates conceptual change
    - Explanation - students generate an explanation of the phenomenon
    - Elaboration - students' understanding of the phenomenon challenged and deepened through new experiences
    - Evaluation - students assess their understanding of the phenomenon" **(https://bscs.org/bscs-5e-instructional-model/)**

The unit includes the "Subtle Shifts Guide for Science Lessons" as outlined in California NGSS Workshops at the Exploratorium, Institute for Inquiry (January 2020). The shifts provide more opportunities for "learner control in lessons" and include the following:

- Use of Science Notebooks during a lesson to record evidence and conclusions.
- Have Science Talks before, during or after a lesson to engage with and make meaning of content.
- Apply a Crosscutting Concept (CC) to the lesson.
- Add or increase learner control of Science Practices (SEP) in lessons.
- Add one or more of the Inquiry Phases to lessons
    - Inquiry starter: Begin the lesson with an exploration to raise questions.
    - Focused investigation: Help students plan and do an investigation.
    - Developing understanding: Create ways for learners to communicate investigation results with others so the whole class can further their understanding.

Lesson 1: Everything is made of matter.
CC: Scale, proportion and quantity
DCI: 5-PS1.A.1

SEP: Constructing explanations and designing solutions

Engage:

- Hand out balloons to each student and have them inflate them. Ask the students to make observations as to what is happening. What is inside the balloon? How is the shape of the balloon changing? How can they control its size?
- Then, get out an empty syringe and a container of water (either demonstrate or have each student do on their own, depending on resources). Place the syringe in water and push, creating bubbles. Where did those bubbles come from?
- If each student has a syringe, have them closely observe the measurements. Make sure that they understand that cc = cubic centimeters which is a measurement of volume. (You may show them that the number of cubic centimeters equals the number of milliliters by filling the syringe with 20 cc of water and releasing it into a graduated cylinder to show that it measures 20 milliliters.)

Explore:

- Hand out two cups each with 100 mL of warm water.
- Distribute 1 tsp of sugar and salt in small containers. Have students describe similarities and differences of salt and sugar, including making drawings in their notebooks.
- Have students dissolve the salt in one container and stir. Dissolve sugar in another container and stir. Ask students what happened to the particles? (They dissolved. Some students may notice that they dissolved at different rates.)
- Mix up the cups and have students do a taste test -- can they tell which container has salt vs sugar without being able to see either substance in the liquid?

Explain: All activities have dealt with *MATTER.* The air in the balloon and the syringe took up space (has volume). The salt and sugar were still in the water even though they weren't visible. *MATTER h*as mass and takes up space. As a class, brainstorm the examples of *MATTER* in the experiments done together. Look around the room and list other examples of matter that can be seen or unseen.

Elaborate: Class discussion. Write the word "cloud" on the board. Discuss whether or not a cloud is an example of matter. Model how to use scientific dialogue. Then, divide students into groups. Give each group one of the following words to discuss: wind, sound, electricity, fire, smoke, stars, light, love. Have them share their thoughts with the class and continue the discussion with the whole class.

Evaluate: In science notebook, have students write down their own definition of matter and write three examples of matter and three non-examples of matter. Have them describe one example and one non-example.

Lesson 2: Matter is made up of particles too small to be seen.
CC: Scale, proportion and quantity
DCI: 5-PS1.A.1
SEP: Planning and carrying out investigation, Using mathematical and computational thinking

Engage: Give each student approximately twenty pieces of Lego and tell them to build something. Then, have them break it back down to its individual pieces and rearrange them into a different creation. How are their first and second creations the same?

Explore: Give each student a piece of paper and a pair of scissors. Tell them to cut their paper in half. Then, take one of the halves and cut it in half again. Continue doing this until the pieces are very small. Will the paper ever just disappear?

Explain: For each of these examples, we can break something large into smaller pieces. *All MATTER is made of PARTICLES that are too small to be seen.* Have students tell their elbow partner how the lego and the paper can represent matter. (The Lego is an example of particles, but on a larger scale. They can be arranged into different formations to make different types of matter -- metal, water, air, etc. The paper can be cut into smaller pieces, but it will never disappear -- it just might be difficult for us to see it with our bare eye. The same is true of matter. Have students share their ideas in the larger group or with all of the students.

Elaborate: Yeast balloon lab.
Materials (per group)-

- Clear plastic or glass bottle with a narrow neck (a water bottle or soda bottle work great)
- 2 Tablespoons dry yeast
- 1 Tablespoon sugar
- 2-3 Tablespoons lukewarm water
- Party balloon
- Bowl or mug full of lukewarm water
- Measuring tape

Procedure- Set up before activity or have students do it…Funnel 2 Tablespoons of dry yeast into the balloon and funnel 1 Tablespoon of sugar into the plastic bottle for each group.

1. Have students funnel 2-3 Tablespoons lukewarm water into the bottle.
2. Note the time in their notebook that they will add the yeast to the lukewarm sugar solution.
3. Place the balloon over the neck of the bottle and pour the yeast into the bottle to start the experiment.
4. Record their observations every 5 minutes by drawing a diagram of what they see.
5. Using a measuring tape, also record the circumference of the balloon in centimeters every 5 minutes (a “mini lesson” on circumference and measuring accuracy may be required).
6. After approximately thirty minutes, have students convert their findings into a graph, with the time intervals on the x-axis and the circumference in cm on the y-axis. Be sure to include a title and labels. Have students observe the trend in their graph. Have students explain what is happening in their notebook. What particles are there that would be unseen without them being trapped by the balloon?

Evaluate: In their journals, have students write down how Legos and particles are similar and different. They should include the vocabulary words “particles” and “matter” in their summary. (One example = Matter has mass and takes up space, and all matter is made of particles that are too small to be seen.)

Lesson 3: Matter comes in different phases.
CC: Energy and Matter
DCI: 5-PS1.A.2
SEP: Developing and using models

Engage: Give students two ice cubes, a cup, a ziploc bag, and access to a digital scale. Have students put one ice cube in the ziploc bag and the other in the cup. Have them weigh both ice cubes, including cup and baggie. Set the ziploc bag ice cube aside. Give them the challenge to try to melt the other ice cube as quickly as possible. Keep all resulting liquids in the cup.

Explore: Ask students, "How did you melt your ice cubes?" Record answers. Then ask, "How could you change it into a gas?" Record answers.

Explain: Matter comes in liquid, solid, and gas states. It usually changes from one to the other due to a change in temperature.

Try this activity to visually represent solids, liquids, and gases::

- Have a marked out area (hula hoop, masking tape box on floor, etc.).
- Have just a few students stand inside the hula hoop. Tell them to move around as much as possible. These students represent the particles in *gas.*
- Add more students. Notice that they cannot move quite as well. These students represent particles in *liquids.*
- Add more students until the space reaches capacity. They can hardly move. These students represent particles in a *solid.*

In their science notebooks, students make a *tree diagram* of the three states of matter. Include a drawing of the particles of each, relating the drawings to the students in the marked out area. As a class, add to the tree diagram using examples from everyday life. Be sure to have a discussion about where snow would fall in the diagram. Have students use their tree diagram to explain the three states of matter to their learning partner. They may revise the diagram as they discuss.

Elaborate: Have students complete the sort activity, using their tree diagram: https://docs.google.com/document/d/1mFzP5GX8UOL21I_q0Y6xPmMjo9bwpL7QuQ57MYpnD3Y/edit. Have them write down questions they have about 2 - 5 items in the sort.

Other options for this day and/or additional days::
1. Molecules in Motion activity
Materials-

- Three small plastic cups per group of students (shot glass size works well)
- Water (enough to fill two of the cups ¾ full)
- Gaseous water such as Club Soda (enough to fill one of the cups in each group ¾ full to represent gas)
- Food coloring (one color per group)
- Salt (approximately a cup depending on the size of your cups and the number of groups in your class)
- Science Notebook for each student

Procedure-
Before activity set up...

1. Set up three very small transparent cups per group.
2. Add water to two of the cups approximately ¾ full, keep one cup with clear water.

3. Add salt to beyond saturation to the second cup so students can see undissolved salt in the cup.
4. Keep the third cup empty to be used later to test the gaseous water.

With students...

1. Pass out the three cups and one food coloring dropper (color doesn't matter).
2. Explain to students that cup one has plain water, cup two has salt water (beyond saturation), and cup three will have gaseous (fizzy) water in it.
3. Tell them that they will be adding 3-5 drops of food coloring into each of the cups and you want them to hypothesize (make educated guesses) as to what will happen to the food coloring. Talk in their groups about what they think will happen. You may have them record their hypothesis in their notebooks.
4. Have students drop approximately 3-5 drops of food coloring into plain water and 3-5 drops of the same food coloring into the saturated salt water.
5. Have students observe closely and draw the results in their science notebooks. Make sure that they label each cup and note what happens to the added food coloring.
6. For notebook drawings, labeling should include:
    - Cup 1: Food coloring in plain water
    - Cup 2: Food coloring in salt water
    - Cup 3: Food coloring in gaseous (fizzy) water
7. When students are done with recording results for cups one and two, uncap the fizzy water and pour into the third cup approximately ¾ full.
8. Immediately have students drop about 3-5 drops of the same color of food coloring.
9. Have students draw the results in their science notebooks.
10. Students need to discuss the results and draw a conclusion. Were their hypotheses correct? What did each of the cup models represent? (solid, liquid, gas)
11. Record in your science notebook other models that can represent a solid, liquid, and gas. (they may draw students in a hula hoop model showing students lined up in systematically in close proximity to show a solid, show fewer students with arrows to show movement/flowing, and lastly draw less students in the hula hoop to illustrate a gas with arrows to show bumping and bouncing.)

Background information- Molecules are always in motion in each of the three states of matter.

- Solid- the molecules in a solid are very close together. They "jiggle" in place because they are so close.
- Liquid- the molecules in a liquid move more freely over and under each other. This movement allows liquids to flow and be poured.
- Gas- the molecules in gases are very far apart. They move the fastest, bouncing off one another.

2. Making Ice Cream in a Baggie activity

Materials-

- Quart size freezer bag for each student (top quality brand only for a good seal and keep salt out)
- Gallon size freezer bag for each student for each student (or a large plastic jar)
- Half and Half- 1 cup per student (or you can use whole milk, but the ice cream will not be as creamy)
- Vanilla extract- 1.5 teaspoon per student
- Granulated sugar- 1 Tablespoon per student
- ¼ cup salt for each student (the type of salt doesn't matter except that the chunkier the salt, the less chance salt is mixed into the ice cream through the bag, so rock salt is recommended)
- Ice

  Please note: You may use ½ cup half and half, ½ teaspoon of vanilla, and 1 Tablespoon of sugar to make less ice cream for each student. One other alternative is to use cream and milk together.

Procedure-

1. Add the half and half, vanilla extract, and sugar into the quart size baggie.
2. Seal the baggie while removing the excess air.
3. Fill the gallon size baggie about half full of ice and add the salt.
4. Add the small sealed baggie to the large baggie containing ice and salt.
5. Add more ice to the large baggie and seal tightly. (Gloves or a towel are needed because the salt makes the ice extra cold.)
6. Shake vigorously for about 6 minutes.

How Does It Work?

Salt is added to the ice for the same reason that salt was sprinkled on icy roads and sidewalks. Salt causes some of the ice to melt and lowers the freezing point. The more salt added, the lower the temperature can get before the saltwater solution freezes. Side note: Why doesn't the ocean freeze? Water normally freezes at 32 degrees Fahrenheit, but a 10% salt solution freezes at 20 degrees F and a 20% salt solution freezes at 2 degrees F.)

Ice has to absorb energy in order to melt, changing the phase of water from a solid to a liquid. When ice is used to cool the ingredients for ice cream, energy is absorbed from the ingredients and from the outside environment (like your hands if you are holding the baggie of ice). The shaking of the baggie moves the warmer cream mixture from the inside to the outside of the bag so it freezes evenly.

Ice cream is a colloid, a type of emulsion. An emulsion is a combination of two substances that don't normally mix together. Milk and mayonnaise are other examples of an emulsion. One of the substances is dispersed throughout the other, with one of the substances often being fat. (Think in terms of oil and water not mixing.) In ice cream, molecules of fat are suspended in water, sugar, ice with air bubbles.

Video (1 minute instruction for teacher viewing before activity if needed)
How to Make Ice Cream in a Bag

Evaluate: Go back to the ice melting in both the ziploc bag and the cup. Weigh them again. What do you notice? Draw a diagram of the water particles both before and after phase change.

Lesson 4: Density and Art
CC: Scale, proportion and quantity
DCI: 5-PS1.A.1
SEP: Developing and using models

Purpose:
This lesson seeks to incorporate art into science by relating particles in matter to the art form pointillism.

Materials-
- Black line template of a Big Bear Scene
- Fine tipped markers (assorted colors)

Procedure-
1. Show students several examples of pointillism. The most famous artist for this medium is Georges-Pierre Seurat.
2. Watch 4 ½ minutes of this 8 minute linked video to demonstrate the method of using small dots to create areas of color to form a picture or pattern.
   Pointillism Techniques
3. Have students notice how the space is filled with small dots that are so close together, they blend together to make a cohesive image. Liken this idea to particles in solids, liquids, and gases. Explain how the closer together the particles are, the more dense they are and, in art, the more vibrant the colors appear. These dense substances would most closely resemble solids. Gas particles are the least dense particles.
4. Give students a black line template of a Big Bear Scene. Provide fine tipped markers. Begin with filling in the water with small dots. Model using different blues to form the liquid, focusing on using a medium density -- the dots aren't too close together and aren't too far away. Then, have them continue the process with the rest of the paper, but remind them to have solids (rocks, trees, etc.) and gases (sky) be less dense.
5. If students finish early, have them design their own picture.

Lesson 5: Phase changes don't affect weight.
CC: Stability and change
DCI: 5-PS1.A.2
SEP: Planning and carrying out investigations, Using mathematics and computational thinking

Engage: Reaction Labs
Materials:
- 3 Sandwich-size plastic zip bags (per group)
- 2 Separate servings of 1 tbsp baking soda (per group)
- 1 Tbsp Lemon juice (per group)
- 1 Effervescent heartburn tablet (per group)
- 1 Tbsp Vinegar (per group)
- 1 Tbsp Water (per group)
- 6 3-oz paper cups (per group)
- 1 Digital Scale (per group)

Procedure-
1. Have students prepare the three baggies.
    - Baggie 1 will contain 1 Tbsp baking soda in a 3-oz paper cup and 1 Tbsp lemon juice in a separate 3-oz cup.
    - Baggie 2 will contain 1 Tbsp baking soda in a 3-oz paper cup and 1 Tbsp vinegar in a separate 3-oz cup.
    - Baggie 3 will contain 1 Effervescent heartburn tablet in a 3-oz paper cup and 1 Tbsp water in a separate 3-oz paper cup.
2. For each baggie, students will weigh the contents before combining them. Tell students to be sure to weigh the bag three times for accuracy and make sure that the edges of the bag are not off the edge of the scale. Have them record their findings in their science notebooks.
3. Without opening the bag, have them combine the ingredients.
4. Record their observations of the reaction they witness.
5. Reweigh the bag, making sure all edges are contained on the scale. Weigh three times for accuracy.
6. Record their findings in their science notebooks.
7. Complete the same process for each bag.

Explore: Discuss how the weight before and after a chemical reaction was virtually the same. Ask students if they think the same will hold true for phase changes.

Melting Lab
Materials-
- 1 Hot plate (per group)
- 1 Digital Scale (per group)
- 4 4-inch aluminum pie pans (per group)
- 2 Oven mitts (per group)
- 1 Pair of goggles (per student)
- 2 Gummy candies (per group)
- 1 Tbsp Shortening (per group)
- 1 Plain snack-sized chocolate bar (per group)
- 1 cup snow from outside (per group)

Procedure-

1. Place one item (gummy candies, shortening, chocolate bar, or snow) into each of the four aluminum pie pans.
2. Record the weight of each substance in the pie pans in their science notebooks, making sure to weigh three times for accuracy.
3. Place the pie pan with the substance on the hot place and allow it to melt (make sure to stir the chocolate and to make sure the snow does not evaporate).
4. Once the substance has changed phase to a liquid, have them record the weight again.
5. Allow liquids to cool and weigh again, as time allows. Have them record observations in their science notebooks.

Explain: Have students explain their findings to their lab partner. (The particles don't disappear, as long as they can be captured, which is why we needed the ziploc bags for our chemical reactions for our first experiments.)

Elaborate: Have students diagram in their notebooks what the particles looked like before and after both the chemical reactions and the phase changes.

Evaluate: Have students write down in their notebooks why the weight of the snow may have changed when turning from a solid to a liquid (evaporation -- particles escaping).

Lesson 6: Phase changes apply to snow and evaporation.
CC: Energy and matter
DCI: 5-PS1.A.2
SEP: Obtaining, evaluation, and communicating information

Engage: Have a small container of water and a small container of rubbing alcohol for each group along with one Q-Tip per student. Have them discuss the similarities and differences of the two liquids. Then, have them use the Q-Tip to apply a small amount of rubbing alcohol on their arms and then a small amount of water on their arms. Which one dries faster? How do they feel different? Ask students to hypothesize what is happening to the two liquids on their arm? Does it disappear? (No, it evaporates)

Explore: Have students gather one cup of each of the following materials: packed snow, loose snow, water, ice cubes. Make sure the cups will not melt under a heat lamp. Have them weigh all four substances in their cups and record the weights in their science notebooks. Discuss how different substances that take up the same amount of space can weigh different amounts. Relate to density and pointillism. Have them draw the particles they believe are present in their journals and predict which substance will undergo a phase change the fastest when heat is introduced. Place ziploc bags over the top of the cups to catch water vapor. Place each cup under a heat lamp and check back throughout the lesson.

Explain: Have students write the following vocabulary words in their notebook a: *temperature, evaporation* (evaporates), *condensation* (condenses), *humidity*. Have them draw examples of each vocabulary word in their science notebooks. Tell them to be ready to use the words to explain how rain was made after the "Making Rain" demonstration.

Making it Rain demonstration:
Materials-
- Ceramic plate or metal pie tin
- Glass jar
- Hot water
- Ice

Procedure-
1. Heat about two cups of water until the temperature is very hot.
2. Pour the hot water into the glass jar (you may heat the jar with water if you use oven mitts to remove.)
3. Immediately place a ceramic plate on the jar to seal the top and place ice cubes on the plate.
4. Students need to record their observations in their notebook.
5. Using the vocabulary words, temperature, evaporates, condenses, to write and share a sentence.

How it Works- The temperature of the water increases when heated. When ice is placed on the plate, some of the hot water in the jar evaporates, rises, then cools and condenses when it reaches the cold plate which forms rain.

Elaborate: Have students return to their heat lamps and baggies and observe what they see. Why is there now water in the zip log bags? Which substances created the most water? Record observations.

Evaluate: Have students review their hypotheses from earlier about which liquid would undergo a phase change the fastest. Were they correct or incorrect? Have them answer the original question and explain what happened using the terms "density" and "evaporation" in their answers. If time, have them predict which would turn into a gas first and why.

Lesson 7: Engineering Focus

CC: Structure and function
DCI: 5-PS1.A.3, 3-5-ETS1.A.1
SEP: Constructing explanations and designing solutions, Asking questions and defining problems

Engage: **Real-world speaker, Mason Perry to discuss his award winning snow-making science fair project that actually went to the State level. He will focus on how he designed his miniature snowmaker and tested it.**

Explore: **Design an Insulator** Begin the class by asking them what happened with the phase change of snow in the last lesson -- which type melted the slowest/fastest? Discuss why. Then, move the discussion to how one might prevent phase changes from happening. Brainstorm together, then explain the task.

Task:
Each student/group will be given 200 grams of snow. Their job is to design a container that will prevent a phase change of that snow. Introduce the term insulate/insulator.

- Provide materials such as different types of cups, fabric, bubble wrap, etc..
- Have students design their prototype in their science notebooks.
- Once the prototype has been approved by the teacher, the student will design their insulator and place the snow inside of it.
- The student will weigh their entire insulator, including the snow, and place it under the heat lamp.
- After ten minutes, have them remove the insulator from the heat lamp and weigh again.
- Have the students make a prediction of what the snow looks like based on the weight.
- Have students open their insulator and observe the state of the snow. If they are pleased with the result, have students place their insulator back under the heat lamp for further testing. If they are displeased with the result, have them redesign their insulator and make appropriate adjustments to their prototype in their science notebook.

Explain: Have students collaborate with others to see which elements were and were not successful and hypothesize why these results were attained.

Elaborate: Have students draw in their notebooks the most effective and the most ineffective design of an insulator based on findings. Do you see these elements in real world insulators? Why or why not? How could these findings help our local mountain with the snowmaking process?

Evaluate: Using the findings above, have students write a *gapless explanation* of the function of an insulator.

Lesson 8: Interactions of geosphere, biosphere, hydrosphere, and/or atmosphere = Art Emphasis
CC: Systems and System Models
DCI: 5-ESS2.A.1
SEP: Developing and using models

Materials-

- Plain white paper
- Blue crayon or colored pencil
- Gray, blue, white, green construction paper
- Optional- a collection of items to glue as examples of the spheres (eg.sand, dirt, bark, sticks, leaves,cotton balls, etc.)

Procedure-

1. Give students a plain piece of paper. Have them shade it blue. Tell them that this represents the atmosphere -- the different gases that make up the air around our planet. Have them write the word *"atmosphere"* in light blue on their drawing.
2. Then, give each student a gray piece of construction paper. Have them draw a mountain skyline on the top of it and glue it to the blue paper. Explain that this gray paper represents the geosphere -- the rocks, sand, and gravel that make up our earth. Have them write the word *"geosphere"* in black.
3. Then, give each student a blue and a white piece of construction paper. Have them cut out some white to add "snow" to the peaks of their mountains. Still using white, have them cut out clouds. Using the blue, have them design a lake. Explain that these elements are all part of the hydrosphere -- the water in all its forms that are present on the earth. Relate this idea to phase changes and what the particles in the snow, water, and cloud are similar, yet different in their density. Have students write the word, *"hydrosphere"* in dark blue on their paper.
4. Then, give students some green paper. Have them cut out triangles to represent trees. Then, give them some plain paper and allow them to add other animals and plants of their choice to glue on. Explain that these elements are the biosphere, or living parts of the Earth. Have them write, *"biosphere"* in green.
5. If time, give students the opportunity to make their paper three-dimensional (possible examples: glue actual sand/dirt to paper, cotton balls for clouds, bark from outside for trees, etc.).
6. On the back of the paper, make a tree diagram of the elements. Have the topic be, "EARTH" and each "branch" be a "sphere". Underneath each of the "spheres", have students sort items underneath each sphere: "Sphere" Sort .

Lesson 9: The water cycle is one way to see the interaction of the earth's spheres.
CC: Systems and System Models
DCI: 5-ESS2.A.2
SEP: Developing and using models

Engage: Have students play the water cycle game. Water Cycle Game

Explore: Have students write down the parts of the "journey" that they remember. Have students use a *flow chart thinking map* to aid organization.

Explain: Go back into the flow map and find evidence of the interaction of different "spheres" discussed yesterday (ex: If a student went to the cloud, they interacted with the atmosphere. If a student was respirated out from a plant, they interacted with the biosphere).

Elaborate: Provide definitions for these terms: *evaporation, condensation, transpiration, respiration, precipitation, accumulation.* Sing together the Water Cycle Song: https://www.youtube.com/watch?v=TWb4KIM2vts,

Evaluate: Have them play the game a second time with a better knowledge of these terms. Then, have them go back to their original flow map and try to define above each arrow which of the terms was occurring at that time.

Lesson 10: Big Bear has its own water cycle.
CC: Systems and System Models
DCI: 5-ESS2.A.2
SEP: Planning and acting out investigations

Engage: Sing the Water Cycle Song. https://www.youtube.com/watch?v=TWb4KIM2vts,

Explore: On pieces of butcher paper, have these terms written: "hydrosphere", "geosphere", "biosphere", "atmosphere". Consider having multiple copies of each to allow better student movement along the room. Put the pieces of butcher paper on the wall. Have students review the definitions of each sphere and how they were a part of the water cycle. Then, allow students to move around the room and write examples of each "sphere" that is present in the Big Bear valley.

Explain: Have students explain the Big Bear elements listed on the papers. Add and clarify as necessary.

Elaborate: Allow students to use turkey trays or some other large, sealed receptacle, to build a three dimensional version of the spheres of Big Bear.

- Beginning with the *geosphere,* allow students to use sand and gravel to construct a mountain range with a basin for a lake.
- Then, using lego from earlier lessons, allow them to add in some elements of the *biosphere* (trees, humans, bears, etc.).
- To integrate the *hydrosphere,* fill a spray bottle with water and "make it rain" at the top of the mountain.
- Ask students to observe where the water goes (downhill, leading to the lake basin). Why is the water there "dirty" (the water picks up particles along the way)?
- Once there has been enough "rain" to almost fill the lake basin, give students sponges to act out *evaporation and condensation,* using them as clouds and squeezing them out over the mountain ranges again.
- Have them do this multiple times and write down what they observe in their science notebook.
- If time, introduce pollution into the scenario by adding three drops of green food coloring to the water in the lake basin. How does the pollution travel through the water cycle? What effect might that have on the *biosphere*?

Evaluate: Have students draw in their notebooks the path the water took in their three dimensional model. Encourage them to use as many vocabulary words as possible.

Lesson 11: Snow is naturally made in the water cycle.
CC: Cause and effect
DCI: 5-ESS2.A.2
SEP: Obtaining, evaluation, and communicating information

Engage: Sing the Water Cycle Song. https://www.youtube.com/watch?v=TWb4KIM2vts, Then, give each student some paper and show them how to make a snowflake out of paper.

Explore: Explain to students that their snowflake is made of paper. Ask them what actual snow is made of. Have them compare/contrast snow and rain (both made of water, one is frozen and one is not, etc.). Ask them why we have snow in Big Bear, but not often in Redlands or Apple Valley.

Explain: Watch this video to gain a preliminary understanding of how snow is formed naturally in the water cycle: https://www.youtube.com/watch?v=Cf6El0mI1fM. Point out that the necessary conditions for snow formation are *temperature and humidity.* Define *humidity.*

Helium Balloon Activity:
Materials-
- Helium balloons (one per group, ideally each balloon would be a different shape and size, no more than six students in a group)
- Legos
- Scotch tape roll

Procedure-
1. Have one student from each group tape one Lego to the outside of the balloon. This process represents a particle of frozen water molecules colliding with another. Let students let go of their balloon. Does it float or sink?
2. Record in your notebook if the balloon sinks or floats in air with only one lego piece.
3. Have students predict as a group how many Legos it will take to "sink" their balloon. Answers will vary based on size/type of balloon. Have students record their hypothesis and findings in their notebooks.
4. Students need to explain why different groups may have had different results (differing balloon types/sizes).
5. If time, allow students to tape their paper snowflakes on to the helium balloon to better symbolize its representation of a snowflake.
6. Have students act out crystals colliding to form snowflakes in their groups..

Elaborate: Have students watch the video again, but this time focus on what happens with the three different weather: warm air, moist air, and cool air. Have students make a flow diagram of each scenario in their science notebooks.

Evaluate: Have students write down in their science notebooks what conditions exist in Big Bear that allows snow to fall here, and not often in places like Redlands or Apple Valley.

Lesson 12: Man made snow at Snow Summit in Big Bear.
CC: Cause and Effect
DCI: 5-ESS2.A.2
SEP: Analyzing and interpreting data

Engage: Have two helium balloons from yesterday in the room. One should be unable to float because of the number of Legos on it, and one should be floating with no Legos taped on. Have a student step outside and put on a pair of snowboarding goggles, a hat, and snowboarding gloves and come inside. Ask the class, "What is the student ready to do?" Ask them which "balloon" represents a situation where snow might occur (sunken balloon) and which one represents no snow (floating balloon). Explain that today looks like a floating balloon and then dramatically pop the Lego balloon. Tell the snowboarder that the conditions aren't right for snow and that he/she has to go home. Have the sad student take off snowboarding gear and return to his/her seat.

Explore: Do our snow resorts want this to happen? Discuss as a class why Snow Summit does not want to turn away customers. Discuss what Snow Summit could do to keep business going, even if natural conditions don't exist for snow to form (they make snow).

Explain: **Real-world Speaker: Wade Reeser, General Manager BBMR** to explain how Snow Summit makes snow (Include the economical and environmental impacts). You can invite a guest speaker, or you can watch the following video: https://www.youtube.com/watch?v=mixEGcOH52Y&t=1465s. As the speaker/video says something important, pause that person/video and have students write down information in their science notebooks.

Elaborate: Have printed out for each group of 5 - 6 students a color copy of the **Wet Bulb Graph**, and also project it on the screen. Together, interpret the graph. For example, write down several scenarios (ex: 50% humidity and 45 degrees) and have students identify whether snow making is Good Snow Quality, Poor Snow Quality, or No Snow Making. Do several of these situations to guide students to see the relationship between humidity and temperature. Snow makers want both humidity and temperature to be low for good snow making conditions to exist.

Evaluate: In their science notebooks, have students make their own rough version of the wet bulb graph. Have them put humidity on the x-axis and temperature on the y-axis. Begin with humidity at 10% and increase up to 100% in increments of 10. Have the temperature begin with 20 degrees Fahrenheit and increase up to 40 degrees in increments of one. Have them use blue colored pencils to shade in regions that represent Good Snow Quality (refer to original Wet Bulb Graph).

Snowmaking Science Source: https://www.snowathome.com/snowmaking_science.php (For more information refer to Reading Resource 6 in the Appendix)

Two of the Most Important Variables in Making Snow are:

1. Temperature & Humidity - The relationship between temperature and humidity is called Wet bulb Temperature.
   Both Temperature and Humidity must be low enough for Snowmaking. Click here to find a live snowmaking weather tool that will give you the current snowmaking conditions where you live. This tool will also give you your snowmaking forecast and snow making history (*how many days you could have made snow last year*). On the weather tool page you will also find a snowmaking weather chart you can

print out to determine if the temperature and humidity are right for you to make snow. This chart also shows Wet bulb temperature. (definition found below)

2. Water temperature, very simply put the colder the better. Commercial snow makers at ski areas typically use water from ponds, this water temperature is usually from 34 to 40 deg. Fahrenheit. Our Snowmakers are designed specifically to be used with household water supply which is typically 15 to 25 degrees Fahrenheit warmer than commercial water supply for ski areas.

Wet Bulb Temperature: The temperature of a water droplet exiting a snow gun is typically between 34 F and 44 F. Once a water droplet passes the nozzle and is released into the air, its temperature falls rapidly due to expansive and convective cooling and evaporative effects. The droplet's temperature will continue to fall until equilibrium is reached. This is the wet bulb temperature and it is as important as dry bulb (ambient) temperature in predicting snowmaking success. For example, snowmaking temperatures at 28 F and 10% humidity are equivalent to those at 20 F and 90% humidity.

SNOWathome.com
Wet-Bulb Temperature Chart
Fahrenheit

Good Snow Quality — Poor Snow Quality — No Snowmaking

Temp (F) \ Humidity	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
20	14	14	14	15	15	15	16	16	16	17	17	18	18	18	19	19	19	20	20
21	14	15	15	16	16	16	17	17	17	18	18	18	19	19	19	20	20	21	21
22	15	16	16	16	17	17	17	18	18	19	19	19	20	20	20	21	21	22	22
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37	26	27	27	28	29	29	30	31	31	32	32	33	34	34	35	35	36	37	37
38	27	27	28	29	29	30	31	31	32	33	33	34	35	35	36	36	37	38	38
39	27	28	29	30	30	31	32	32	33	34	34	35	35	36	37	37	38	39	39
40	28	29	30	30	31	32	32	33	34	34	35	36	36	37	38	38	39	40	40

Wet bulb temperature is the lowest temperature that can be obtained by evaporating water into the air at a constant pressure. The term comes from the technique of wrapping a wet cloth around a mercury bulb thermometer and blowing air over the cloth until the water evaporates. The wet bulb temperature is always lower than the dry bulb temperature, but will be identical with 100% relative humidity.
This wet bulb temperature is what snowmakers use to know when they can make snow. You can see it is possible to make snow when the temperatures are above freezing but only with very low humidity.

Plot your current temperature *(red numbers on the left)* to the % of humidity *(blue numbers on the top)* and where they meet the *(black numbers)* is your current wet bulb temp.
Any time the wet bulb number is below 20 degrees Fahrenheit (blue shaded area) snowmaking is at its best… nice dry snow. You can make snow from 21 degrees to 27 degrees wet bulb *(purple shaded area)* but the snow will be wet.

Snowmaking Temperature & Humidity Guide

Air Temperature °F	Relative Humidity % 20%	30%	40%	50%	60%	70%	80%	90%	100%	Snow Quality Key
	Wet Bulb Temperature °F									Ideal / Marginal / Not Possible
14.0	9.9	10.4	10.9	11.5	12.0	12.4	12.9	13.5	14.0	Ideal Snowmaking Conditions
15.8	11.3	11.8	12.4	12.9	13.5	14.0	14.7	15.3	15.8	
17.6	12.7	13.3	13.8	14.5	15.1	15.8	16.3	16.9	17.6	
19.4	14.0	14.7	15.4	16.0	16.7	17.4	18.0	18.7	19.4	
21.2	15.4	16.2	16.9	17.6	18.3	19.0	19.8	20.5	21.2	
23.0	16.9	17.6	18.3	19.0	19.9	20.7	21.4	22.3	23.0	Marginal Snowmaking Conditions
24.8	18.2	19.0	19.8	20.7	21.6	22.3	23.2	23.9	24.8	
26.6	19.6	20.5	21.4	22.1	23.0	23.9	24.8	25.7	26.6	
28.4	20.8	21.9	22.8	23.7	24.6	25.5	26.6	27.5	28.4	
30.2	22.3	23.4	24.3	25.3	26.2	27.3	28.3	29.3	30.2	Snowmaking Not Possible
32.0	23.7	24.6	25.7	26.8	27.9	28.9	30.0	30.9	32.0	
33.8	25.0	26.1	27.3	28.4	29.5	30.6	31.6	32.7	33.8	
35.6	26.4	27.5	28.8	29.8	31.1	32.2	33.3	34.5	35.6	
37.4	27.9	28.9	30.2	31.5	32.5	33.8	35.1	36.3	37.4	
39.2	29.1	30.4	31.6	32.9	34.2	35.4	36.7	37.9	39.2	
41.0	30.6	31.8	33.1	34.5	35.8	37.0	38.5	39.7	41.0	
42.8	31.8	33.3	34.7	36.0	37.4	38.8	40.1	41.5	42.8	

"The most important thing we should care about for the guns to start and keep on cranking is having a Wet Bulb Temperature of 27 degrees F or less. What are the right weather conditions to get down to that critical number? It is a combination of Air Temperature and Relative Humidity."...Steve Andrews
https://theskimonster.com/blog/posts/when-do-ski-areas-start-making-snow/

Lesson 13: Expedition to Snow Summit.
CC: Cause and Effect
DCI: 5-ESS2.A.2
SEP: Obtaining, evaluating, and communicating information

Note: Plan ahead for parent volunteers to chaperone.

Engage: Before leaving, have students brainstorm ideas of what they will see at Snow Summit on their snowmaking tour. Record ideas in a notebook. Also ask students to write down questions that they would like to ask the staff.

Explore: Ask students to closely observe as much as possible while on the structured tour with a knowledgeable employee. Have them bring their science notebooks and take notes on what they see. Have them draw diagrams of the snow making equipment and ask as many questions as possible.

Explain: Have students explain the snowmaking process to a learning partner.

Elaborate: Draw a diagram in your notebooks to help someone understand the process.

Evaluate: In their science notebooks, each student writes a *gapless explanation* describing how to make snow. When students return from the expedition, they will share their gapless explanation at their table group to create one collective explanation to be shared aloud with the class.

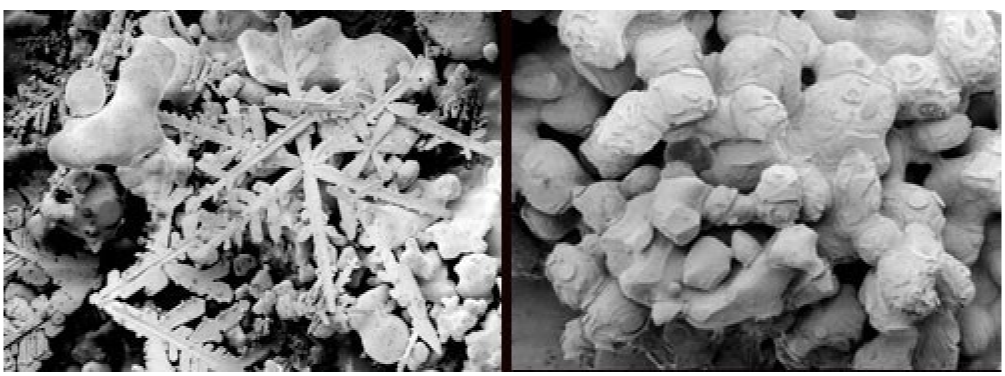
Lesson 14: Compare and contrast man-made vs. natural snow in theory.
CC: Cause and Effect
DCI: 5-ESS3.C.1
SEP: Engaging in argument from evidence

Explore: Make a large grid like the one below on a large piece of butcher paper. Give students two sets of post-it notes in two different colors, approximately twenty of each. Assign one color as a "pro" and the other color as a "con". Define each category in the table below. Give students five minutes to fill out as many post-it notes as they can for natural snow (ex: A pro for natural snow in environmental impact is that it doesn't take any energy to make. A con for financial impact is that natural snow cannot be depended upon, so it may mean fewer skiers coming up to Big Bear, which means less money for Snow Summit). Allow students to put their post-it notes on the chart in the appropriate place.

As a class, look for similarities and patterns in each column. Notice the prevailing color -- were there more pros or cons? Then, do the same for man-made snow. Once all post-it notes are on the board, see which color is more dominant and in which category/row. Have students summarize their findings in a double-bubble map in their science notebooks.

	Environmental Impact	Economic Impact	Community Impact
Natural Snow			
Man-Made Snow			

Have a class discussion about the pros and cons of this type of snow making using the grid as a guide. Students will most likely come to the conclusion that making snow using polymers is not an economically possible choice.



The image on the left is a close-up of natural snow. The one on the right is man-made. So it turns out there is merit to the notion that natural snow is better. Photo: Courtesy of NASA

<u>Activity: Making Fake Snow (Insta-Snow)</u>

Purpose-

1. This activity allows students to investigate another alternative to snowmaking at parks. Insta-Snow is used in indoor snowboarding parks throughout the world. There are benefits and negative impacts which need to be discussed by students.
2. This activity will allow students to see “physical”changes beyond water forming into ice. These are not examples of a chemical change or reaction because a new substance is not formed. Both the ice and the super absorbent polymer (Insta-snow) can change back to their original form. Ice will melt with heat and the water will evaporate from the snow to bring it back to powder.

Materials-

- Two 1ounce plastic cups for each group or partner
- ½ teaspoon of Insta-snow powder in one cup for each group
- 1 ounce of room temperature water in the other cup for each group
- Tray or plate for each group

Procedure-

Set up before the activity...You will need two 1 ounce cups placed on each tray. Put ½ teaspoon of Insta-Snow powder into each 1 ounce cup. Fill one of the cups with 1 ounce of room temperature water.

1. Teacher Demo as an engager: Ask students to predict what happens when water is added to a variety of different familiar substances such as salt, sugar, flour, corn starch substances.
2. Pass out the tray with the “mystery substance” in it and have students observe it closely (without tasting) to predict what it is and what will happen when it is placed in water.
3. Tell students to keep the tray/plate under the cup (The snow will overflow out of the cup when the water is added, but don’t spoil the fun by telling them that part.)
4. Have students pour the one ounce cup of water into the cup with the Insta-snow all at the same time. Most students don’t correctly predict what it is or what it does.
5. Have students discuss the uses of the “mystery substance”.
6. Include in their discussion, the environmental and economic impact.

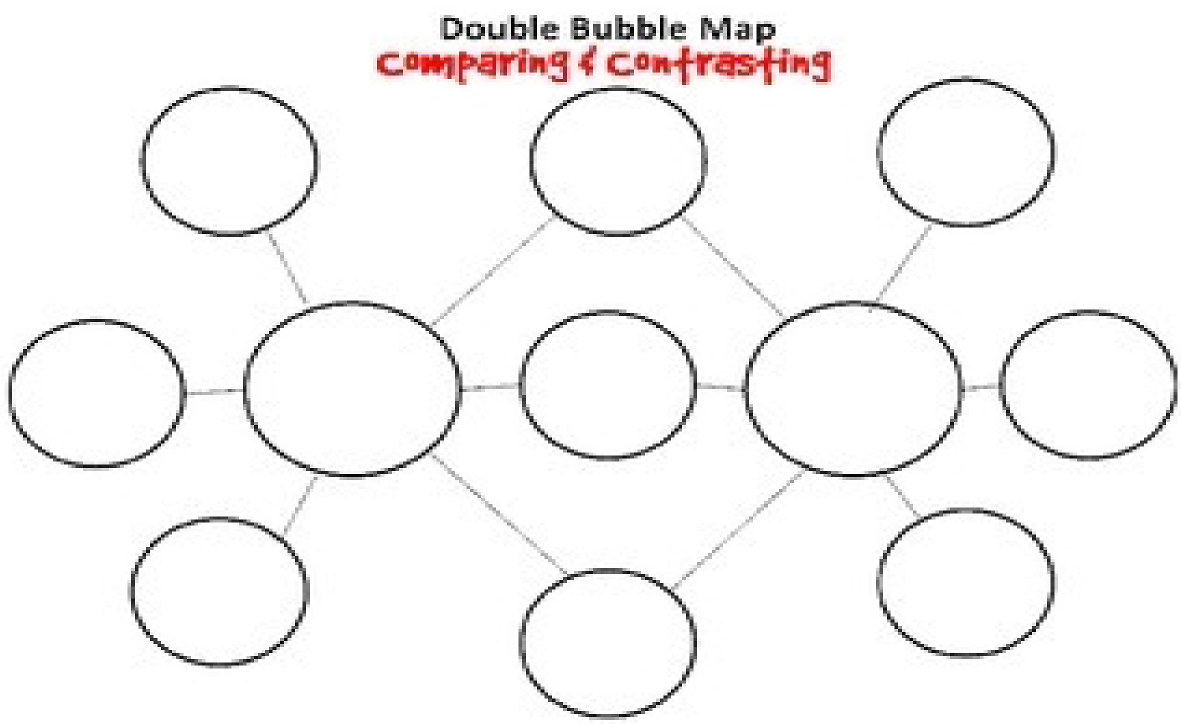
How it works:

Insta-Snow is a synthetic polymer with super water-absorbing properties. The powder expands to 100 times its original volume. (On a side note, 1 pound of Insta-Snow® powder will make almost 8 gallons of fluffy fake snow!) Insta-Snow is derived from the superabsorbent polymer found in baby diapers. However, it not only absorbs water, but the long chains of molecules swell to a huge size causing it to expand which is different from diapers (for obvious reasons). The snow polymer soaks up the water through osmosis with the polymer chains having elastic properties allowing them to stretch, but only to so far, holding only so much water. After use, the water can evaporate over time and the snow polymer can be reused.

Lesson 15: Compare and contrast man-made vs. natural snow in person.
CC: Structure and Function
DCI: 5-ESS3.C.1
SEP: Obtaining, evaluation, and communicating information

Engage: **Real-world speaker, Tim McKelvey, Snow Summit Lead Snowmaker** will use the miniature snowmakers built from the previous year to make snow either at BBES or at Snow Summit.

The goal of this day is to create hands-on experiences with both man-made and natural snow.
You may use a "Double Bubble" thinking map:



Center ideas for experiential learning opportunities::
Sledding -- time a certain sledding hill and also rate on a scale of 1 - 10 in terms of enjoyment.
Snowballs -- set up a target. Measure how easy/difficult it is to make a snowball and how accurate throws are.
Close Up Investigation -- use magnifying glasses to analyze shape/structure of different samples. Measure the same volume of snow from both man-made and natural and see how quickly a student's breath can melt it.
Skiing

Lesson 16: Pros and Cons of making snow.
CC: Structure and Function
DCI: 5-ESS3.C.1
SEP: Engaging in argument from evidence

Make a pro/con list of making snow.

1. View the 2 minute video linked below and have students write in their notebook all of the things noted by the meteorologist that must be considered when making snow.

   Video (2:13): Man-made vs. mother nature: The cost and science behind making snow by Meteorologist Cassie Wilson, Thursday, October 26th 2017

2. Read this article together and brainstorm more considerations when making snow.

   Snow-making -- It's a million-dollar industry trying to take on Mother Nature.

The ultimate goal in snow-making is to get area ski resorts open early, but also to add to the snow pack throughout the year.

Over the last six years, Squaw Valley Alpine Meadows has invested $9 million into snow-making. And it seems to be paying off; in recent years, both Squaw and Alpine received their highest ever snow surface ratings, improved their efficiency, and improved their capacity.

Mark Meyer, the snowmaking manager at Squaw, has 20 years of experience making snow and has seen those $6 million dollars make major strides:

> "Snow-making has changed a lot here at Squaw; we've become more efficient. And that's kind of the goal in snow-making nowadays, because power is very expensive, the water that we use, everything costs money and so the more efficient we can be... The faster we can turn the system on and off, the better"

Squaw Valley Alpine Meadows has invested in every aspect of snowmaking: personnel, snow guns, pipelines, and technology.

That includes high-efficiency guns, improved air compressors, new and newly replaced air and water lines, increased wages, a state-of-the-line command center and automatic air and temperature sensors on each of their 150-plus snow guns.

But how does man-made snow stack up to mother nature? Mark explains:

> "Snow-making snow is said to be like two-week old natural snow. It's got a very high water content, it's very dense, it lasts longer than natural snow when the sun is beating on it because of the high water content."

The magic number for making snow is a wet bulb temperature of 27 degrees. A wet bulb temperature differs from a regular temperature because it factors in humidity. The lower the humidity, the colder the wet bulb temperature.

Squaw hit this magic number for the first time this season, on Friday, October 20, and were able to fire up their snow-making machines. Although October is ending warm, Squaw Valley Alpine Meadows is still shooting for an opening date of November 17, 2017.

Reno, Nev. (News 4 & Fox 11)

3. Research other ski resorts and see what trends are apparent. See information gathered from websites at the end of this document.

Reading Resource 1: Snow-making 101 **Source:**
https://www.libertymountainresort.com/winter-sports-liberty/mountain/snow-grooming-report/snowmaking-101

Reading Resource 2: Difference Between Man-made and Natural Snow **Source:**
https://newtoski.com/snowmachine-vs-natural-snow/

Reading Resource 3: How We Make Snow **Source:**
http://www.skiroundtop.com/how-we-make-snow

Reading Resource 4: How Much Does it Cost to Make Snow at a Ski Resort? **Source:**
https://emsenv.com/2016/06/08/cost-to-make-snow/

Reading Resource 5: Cost of Snow-making**Source:** https://adventure.howstuffworks.com/outdoor-activities/snow-sports/snow-maker6.htm

Reading Resource 6: The Science Behind Snowmaking
Source: Robert Pursell, Men's Journal 2019

Lesson 17 - 20: Design final project based on answering this question: "Should Snow Summit continue to make snow?"

Final project should include:

- Provide a gapless explanation of how snow is currently made, both naturally and at Snow Summit, with description including some specific vocabulary words (humidity, evaporation, pressure, etc., TBD)
- Pros and Cons summary of current system
- Personal view with reasoning

Overall Facilitation Goals for Project:

- Students will create these presentations using as much technology as possible -- videos, Google presentations, etc.
- Students should be given a chance to collaborate during their presentations. Do we want them to be able to work in partners/groups, or simply communicate with each other and the teacher during production?
- Students should be given the opportunity to present products and respond to feedback from both peers and teacher before final presentation.
- Students should be given the opportunity to, after feedback and refinement, present their presentations to a real-life body of stakeholders (Snow Summit reps, EdTrust, School Board, etc.)

Appendix

Standards Addressed in the Snow-making Unit

Structure and Properties of Matter

5-PS1.A.1 Disciplinary Core Idea Structure and Properties of Matter: Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.

5-PS1.A.2 Disciplinary Core Idea Structure and Properties of Matter: The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.

5-PS1.A.3 Disciplinary Core Idea Structure and Properties of Matter: Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)

Earth's Systems

5-ESS2.A.1 Disciplinary Core Idea Earth Materials and Systems: Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). The ocean supports a variety of ecosystems and organisms.

5-ESS2.A.2 Disciplinary Core Idea Earth Materials and Systems: Earth's systems interact in multiple ways to affect Earth's surface materials and processes. The ocean shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Human Impact on Earth's Systems

5-ESS3.C.1 Disciplinary Core Idea Human Impacts on Earth Systems: Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space.

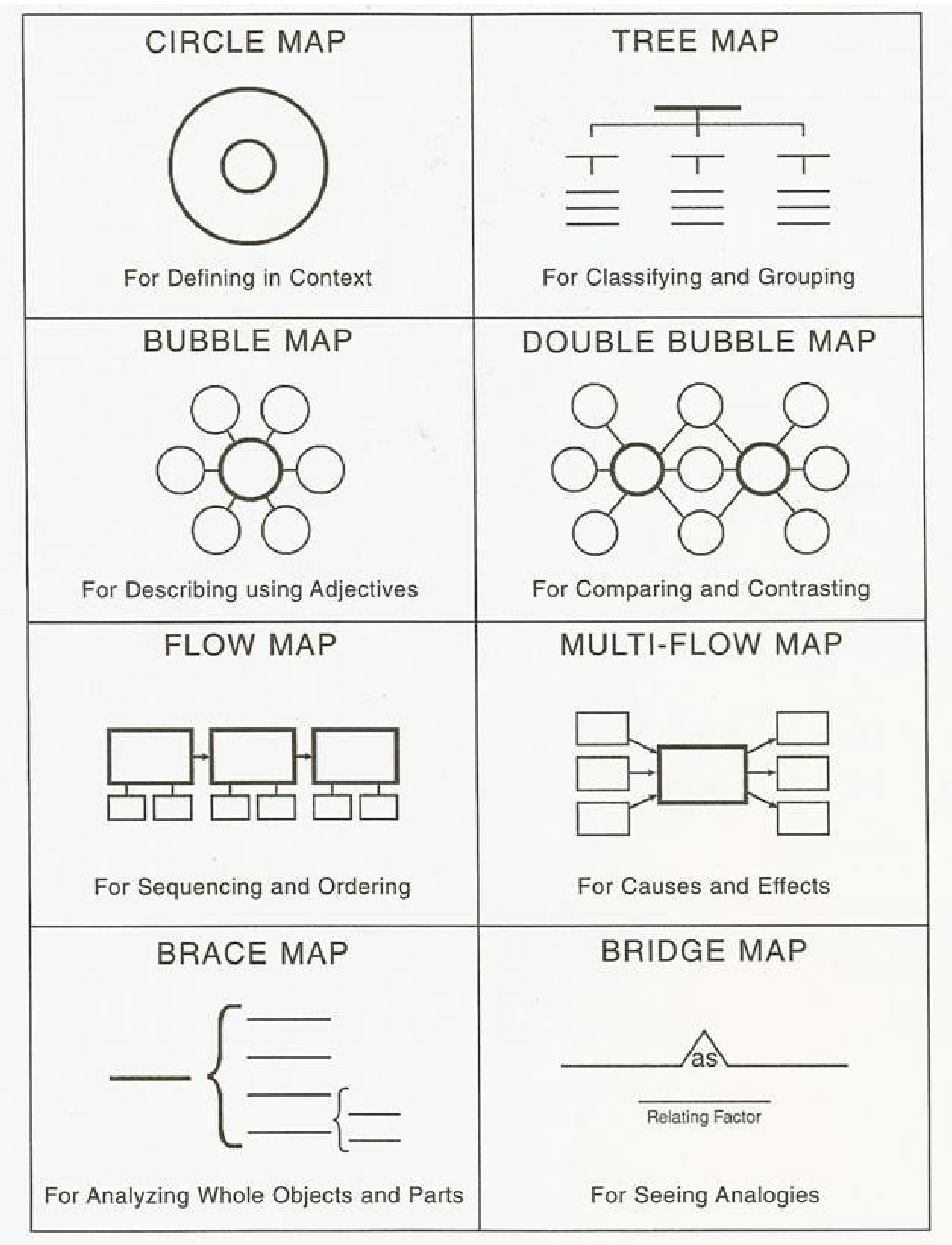
Engineering Design

3-5-ETS1.A.1 Disciplinary Core Idea: Defining and Delimiting Engineering Problems: Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

What are Thinking Maps?

"Thinking Maps are consistent visual patterns linked directly to eight specific thought processes. By visualizing our thinking, we create concrete images of abstract thoughts. These patterns help all students reach higher levels of critical and creative thinking — essential components of 21st Century education. In a school-wide implementation, Thinking Maps establish a consistent Language for Learning."
https://www.thinkingmaps.com/why-thinking-maps-2/

Video (5 ½ minute): **Why Thinking Maps**



Some of the lessons ask students to draw a "thinking map" to assist critical and creative thinking.

Reading Resource 1: Snow-making 101

Source:

https://www.libertymountainresort.com/winter-sports-liberty/mountain/snow-grooming-report/snowmaking-101

Liberty Mountain has one of the best snowmaking systems in the ski industry! 100% of our terrain is covered by snowmaking, so as soon as we have cold temperatures, we can have snow all winter long, even if we get no natural snow at all. Making snow is more than just waiting for the weather to be cold enough to fire up the snow guns — there are 6 key elements that need to be in place before we begin to make snow:

- Cold temperatures
- Low humidity
- Compressed air
- Water
- Snow guns
- Snowmakers & groomers

Cold temperatures

First and foremost, we absolutely need cold weather in order to make snow. No equipment arsenal in the world can produce good machine-made snow without it! 32 degrees Fahrenheit is the freezing temperature for water to turn into snow crystals, but ideal snowmaking conditions call for temperatures to be 28 degrees or lower.

Low Humidity

Aside from air temperature, our snowmaking staff at Liberty Mountain also keep an especially close eye on the wet bulb. The wet bulb temperature is a combination of the air temperature and the humidity, and is the most critical indicator for snowmaking. A wet bulb in the low to mid 20s means we can even make snow at or above 32 degrees in some situations! In a nutshell, as the temperature and humidity drop, the amount of snow made per hour goes up.

Compressed Air & Water

Water and compressed air is the combination that creates our snow! Compressors create the compressed air (41,000/cfm) which is then pushed through miles of snowmaking air pipes that line the mountain. Another set of parallel snowmaking pipes is used to pump up to (7,300/gpm) of water up the mountain. All the water is drawn from our snowmaking pond located in our base area, converted into snow over the winter, and then returned naturally to the water table and pond in the springtime when the snow melts.

Snow Guns

The snow gun serves as the mixing chamber for the water and air. The 350 snow guns at Liberty Mountain vary in their specific function and location on the mountain, depending on how they create, blow, and position the snow.

Machine made snow is more durable than natural snow, and is actually better for getting a great snow base here at Liberty! Natural snowflakes have 6 arms, or dendrites that spread away from the flake's core, and create the symmetrical crystals that make them so pretty — but also makes them so fragile! Machine-made snow on the other hand is a simple ball of snow — no arms to break off and get compacted down, thus being more durable for creating and maintaining a base.

Snowmaking and Computers

Another aspect that makes our snow guns so special is that much of our system is computerized. Once the conditions on the mountain reach ideal snowmaking temperatures and humidity levels, our York snowmaking system automatically fires up the snow guns, and fine tunes each individual gun's setting based on the conditions at each strategically placed weather station located up and down our trails. This means we can have the entire computerized system up and making snow in less than an hour — so as soon as we get Mother Nature's cooperation, our slopes will be blanketed in white in no time at all.

So, how much snow can be made in an hour?

Thanks to snowmaking upgrades in the 2019 off-season, we will be able to increase our water flow from 4,500 to 7,300 gallons per minute! Which means, at the ideal snowmaking conditions of a 20 degree wet bulb...

- We pump up to 7,300 gallons of water per minute
- Each gallon of water weighs 8.33 lbs
- Multiply the two (gals per min X weight) you get 60,809 lbs of water being turned into snow per minute
- Divide that number by 2,000 (# of pounds in a ton) you get 30.4 tons of snow per minute
- Multiply that by 60 (minutes per hour) that's 1,824 tons of snow per hour!

Snowmakers and Groomers

The final touch in the snowmaking process is our staff! Our snowmakers and groomers are on call 24 hours a day, 7 days a week to be on the mountain, taking advantage of ideal conditions the moment they arrive. They work all night to prepare the mountain for you to enjoy skiing, riding and tubing. Even when we don't get to make snow on a certain night, the grooming staff will be hard at work all night to get the slopes looking and feeling like there is a nice fresh coat of snow — look at that corduroy!

There is a lot that goes into snowmaking here at Liberty, with several departments and millions of dollars in equipment working together. It all starts with Mother Natures blessing us with ideal snowmaking conditions... so get ready, because she can't hold out too much longer

Reading Resource 2: Difference Between Man-made and Natural Snow
Source:
https://newtoski.com/snowmachine-vs-natural-snow/

So you've heard that ski resorts can make snow, and you might be wondering: *so what's it like? Can you tell the difference when you ski on it?* Great questions and here's the answer:

Man-made snow is snow, it's just made by snowmaking machines pumping water droplets at high speed through a condenser, rather than naturally falling from the sky. Natural snow has a complex crystalline structure whereas snow from snow machines is simple frozen fragments.

It's good to ski on and **most skiers would not be able to tell the difference between a groomed slope that has machine snow and one that's all natural --** unless that is you compare it to fresh powder.

**Fake snow or dry ski slopes are different surfaces -- they're not snow.*

***I use the word 'snow guns', 'snow machines' and 'snow cannons' interchangeable below -- it's the same thing.*

What is it like to ski on machine snow?

Skiing on machine-made snow pumped from canons is fun and similar to skiing on natural snow, but it is denser and a tiny bit rougher to ski on and does pack down into ice faster.

Most ski runs are a mixture of natural, weather-made snow and machine-made snow, so the final makeup of the ski run is usually blended together over time (unless you ski directly below a ski canon that is blasting out ice crystals).

Snow from snow guns is still cold, wet and very snow-like. It's not until you look a bit closer that you see how the crystalline structure is quite different.


© Photo by NASA

NASA scientist Dr. Peter Wasilewsk looked at machine snow and natural snow under a microscope to see the difference. As you can see in the image above, natural snow on the left is more delicate and complex. This structure makes it lighter and fluffy when it's freshly fallen -- but also easier to break.

The image on the right is machine made snow which is made of more simple clumps of ice and more closely resembles snow after it has been packed down by other skiers

This difference in structure makes it denser, which is great for ski racers on downhill events who want a hard almost icy surface (race courses are injected with more water and packed down much harder unlike normal groomed pistes) for their sharp edges and ambition to go as fast as possible.

For powder lovers, there is nothing like the real thing, although without snowmaking machines many ski resorts would not be able to open early or stay open when the weather doesn't provide. [Snow machines have become so popular that over 90% of U.S. ski resorts now have them installed, source.]


Photo by Antti Nissinen

Machine snow is wetter (typically twice as wet) than natural snow which makes it lump together faster. Because natural snow is drier, you'll feel lighter and more buoyant as you ski through it compared to the wetter machine snow (source).

One major benefit of artificial machine snow is that it lasts longer (great for ski competitions) and is more resistant to rain, making it a good base for natural snow to fall onto.

If it rains, machine snow is more likely to hold together for longer (less fragile) but it also gets slushier faster because of the already high water content.

Snow-making snow is said to be like two-week old natural snow. It's got a very high water content, it's very dense, it lasts longer than natural snow when the sun is beating on it because of the high water content.

> Mark Meyer, Squaw Resort

However, the truth is most skiers (especially new skiers) won't be able to feel the difference between a groomed ski run made entirely of natural snow and another made predominantly from machine snow. That's because groomed pistes are compacted by other skiers and snow plows, and so the surface on both will feel pretty similar.

> Once it's been cut up and groomed by the machines, no one can tell.
>
> Richard P, Manager at Peisher Ski Resort

If you had two slopes and one was virgin untracked powder and the other fresh cannon snow (and you momentarily hid the machines and somehow leveled it out without compacting it), then the average intermediate skier would likely feel the difference.

All said, there are different types and qualities of natural snow and machine snow and the final texture depends on the humidity and temperature as it forms and onto what base snow it comes into contact with.

If you're interested, I just wrote an article all about the different snow you'll find on the mountain here: Skiers Guide to Different Types of Snow

How is natural snow made?

Natural snow develops when water vapor in clouds freezes and falls to the ground. Snowflakes are made up of hundreds of these frozen crystals that form around small specs of dirt in the air.

Snowflakes grow in complexity and size as they fall to the ground and take on wonderfully unique structures. Yes, it's true: every snowflake is different -- that's because each snowflake charts a unique course through different air currents that effect on a microscopic level how the crystalline structure grows.

Once fallen snow can take on many forms, starting off as fresh powder and turning to crud, packed, concrete and various other forms of snow that skiers know it as.

Machine-made vs natural snow?

Man-made snow is real snow, its just artificially made by pumping water droplets at high speed through a snow canon when the temperatures are below -2°C (28°F) source.

Machine made snow is great to ski on, but it is not as light or fluffy as natural snow because its crystalline structure is not as complex.

Many resorts (at huge expense) use cannons to supplement their natural snowfall and keep their groomers open throughout the season. While snow cannons are becoming more efficient, they still require huge amounts of water to be pumped uphill and consume lots of electricity.

While writing my article: Why do ski resorts with snow close early? I found out that some mid-sized resorts may spend $30-40,000 per day making snow! Luckily resorts tend to run their cannon at the start of the season to guarantee the opening of groomers if the weather doesn't produce.

How is artificial snow made?

Artificial snow is made by pumping millions of tiny water droplets into the air so they freeze and fall to the ground.

There are two main types of snowmaking machines -- one that uses compressed air and water and the other that uses a fan and water -- both atomize water. Snow machines use nucleators (like *Snomax*) that they inject into the water to increase snow products. like *Snomax.*

Snomax is a made from freeze-dried bacteria commonly found on the leaves of plants (source). Like natural snow, this provides a spec of matter for ice crystals to more quickly form around each droplet. The end result is more snow from the same amount of water at warmer temperatures.

Snow Science: Snowmaking Part 1 - Making Snow on the Mountain

#1 Compressed air

This type of machine uses the compressed air to fire the water at very high speed, splitting it up into tiny particles that travel further across the slope.

- **Pros:** *Travels further, less electricity.*
- **Cons:** *You need two inputs.*

Compressed air snow lance

#2 Fan snowgun

This type of machine uses an electric fan to blow the stream of water into drops. Also known as an airless snowgun.

- **Pros:** *Doesn't require compressed air.*
- **Cons:** *Requires more electric power.*

Fan snow gun. Photo by Leo-setä

Operating Temperatures 🌡

Snowmachines can't run all the time and they need to be within a specific temperature to work. Technically machines start to work below freezing (and sometimes above, more on that below) but a more efficient temperature is -2**°C (28°F)** or below when more snow can be produced and it is less at risk of melting as soon as it is made.

On a warmer day, snowmaking machines can be set to make smaller droplets so more of them freeze (but this does make a smaller pile of snow). While on a colder day the droplets can be lager to make more snow.

It can get too cold for snowmaking machines to operate, and if the machine is running below -20°C+ (-2°F+) and the water stops because of a power outage, the pipes can freeze, explode and destroy the expensive machines.

However colder temperatures are always better for snow production.

Humidity

The temperature is not the only factor, in fact, humidity is just as important when it comes to the amount of snow that can be made.

Snowmakers use the wet-bulb temperature (WBT) to determine whether they can operate a machine or not. The WBT is the temperature read by a thermometer covered in a water-soaked cloth plus moving air (source) -- similar to what the water droplets experience as they are thrown from the cannon.

It's essentially the temperature and humidity combined. Snowmaking machines can operate even at high temperatures -- up to 4°C (40°F) -- but with low humidity (source)

The lower the humidity the more snow can be produced per hour. The ideal humidity is less than 30% but ideally when it's in the low teens. Snowmaking is more efficient in low humidity (when the air is less saturated with water) because water cools faster (source), therefore making larger snow crystals from each droplet.

The best weather for snow production is cold and dry.

Infrastructure

There's more to snowmaking than placing cannons around the resort. A whole host of hidden infrastructure needs to be set up to feed water, electric and pressurized air to the snow systems.

You need massive amounts of water and electricity to power snow canons and it's said that on average 50% of an average American ski resort's energy costs come from snow production (source).

Photo by Lietmotiv

Water 💦

It takes about 401 liters (106 gallons) of water to produce one cubic meter (35 feet³) of snow. The average snow making machine makes that much snow in 1 minute! (source).

Although 80% of water used eventually ends up at its source once the snow melts, it can limit the amount of water for communities lower down the mountain and have some environmental consequences to the area (source).

Electricity 💡

1-14kwh per cubic meter of snow depending on the conditions and the efficiency of the machine (source). All this electricity goes to power the pumps, the fans and the pressure jets.

Computer systems 💻

Hi-tech computer systems are often installed to constantly monitor humidity and temperature and adjust the pressure to maximise snow conditions.

Labour ⚒

It takes a skilled workforce to manage the machines, keep them running, move them around the slopes and a small army of snowplows to spread out the snow.

Photo by Rudi Riet

How much does it cost to make snow? 💰

There's no mistaking, snowmaking is very expensive. It costs between $1-2,000 to cover one acre (4046 meter²) with 12 inches (30cm) of snow (source). Although it's still cost-effective otherwise ski resorts wouldn't invest so heavily in snowmaking technology.

The organization Protect Our Winters estimates that the ski industry would suffer a loss of $1,07 billion per year without being able to make their own snow. That's because they can open early, stay open for longer and hold ski competitions.

With the ski season being only 5-6 months, each ski day the resort can stay open, the more revenue they can generate. That is up until spring and early summer when visitor numbers drop off and many resorts will close even when there is enough snow to stay open.

Behind the Scenes

This is a cool video showing the technical art of snowmaking at Calabogie Peaks Resort.

Behind the Scenes - How Snowmaking at Ski Resorts Works

Snowmaking & Global Warming

According to the European Environment Agency, since 1970 the length of the snow season in the northern hemisphere has **decreased** by five days each decade (source).

The Rocky Mountains, for example, have lost 20% of their spring snowpack.

The latest statistics published in 2016 show that over the period from 1967-2015 snow cover has decreased by 7% on average in March and April and by 47% in June. In Europe specifically, the numbers are even more worrying (13% & 76%).

This is a worrying trend and means the demand for artificial snow is only going to increase. Hopefully, advances in technology can make for more sustainable and less energy intensive snowmaking -- otherwise, the environmental cost and the cost of ski passes is going to rise.

Final thoughts

As much as we'd all love to only ski on natural snow, snowmaking is now, unfortunately, an integral part of skiing.

P.S If you're worried about skiing on machine-made snow, don't be, it's pretty much like skiing on a groomed piste.

Author Simon Naylor

Reading Resource 3: How We Make Snow
Source:
http://www.skiroundtop.com/how-we-make-snow

How We Make Snow

Each winter, an amazing transformation takes place at Roundtop Mountain Resort. Even though Mother Nature does not provide much snow in this region, the slopes are always covered with fresh snow. How do we do it? We're glad you asked!

Machine made snow is made up of exactly the same stuff as natural snow - frozen water. When the weather provides cold temperatures, but no moisture, our snowmaking team simply adds just the right amount of moisture to the atmosphere to produce excellent snow. It may sound easy, but making great snow requires millions of dollars in specialized equipment and an experienced team of snowmakers.

You may have heard people say that machine made snow is more durable than natural snow. Believe it or not, it's true! here's why:

The classic six sided natural snowflake is soft and fluffy when it falls from the sky. That's why natural snow can be so fluffy at first - it is mostly air. However, over time the little branches break off and because of the greater surface area the crystal melts faster too. The properties of the snow change dramatically.

Machine made snow looks more like little round balls. As time goes by, the machine made crystal may shrink, but the basic shape stays the same longer. Since it is a ball, it has a smaller surface area so it melts slower too. Therefore, you can groom and ski on machine made snow and it will retain it's original properties longer.
We Work With the Weather

Now a little bit about the weather. Just like Mother Nature, we need temperatures of 32 degrees or lower to make snow. But 32 doesn't always equal 32! Snowmakers work from the "Wet Bulb" temperature. The wet bulb takes the amount of humidity in the air and evaporative cooling into account. The wet bulb temperature is usually colder than dry bulb (the kind most people use) so it may appear that we can make snow above 32 degrees at times. The rule of thumb is that as the temperature and humidity go down, the amount of snow we make goes up!
It All Begins As Water

Roundtop Mountain Resort has snowmaking ponds with a total capacity of over 35 million gallons! All of the machine made snow you see on the slopes started out in our snowmaking ponds...and will eventually return there after the ski season ends.

In order to make snow, we need to pump cold water up the hill - with our new pumps that's 5,000 gallons per minute when running at full capacity. Our vertical turbine water pumps take water from the ponds and pump it up the mountain. You may notice the fountain in the snowmaking pond near the maintenance area. That's not just for looks, it helps cool the water, which makes snowmaking work better.
Air is the Other Half of the Equation

But water is only half of the story. Most snow making equipment also requires compressed air to propel the water into the air. Our compressors can produce up to 30,750 cfm of air at full capacity. Producing compressed air is the most expensive part of snowmaking. Fortunately with the installation of new high efficiency snowmaking equipment our need for compressed air has gone down dramatically allowing us to make more snow, faster, while using less energy!

Unfortunately, compressed air comes out of the compressor very hot (180 degrees), obviously not good for snowmaking. Before the air goes up the hill, it is run through huge air coolers to bring the temperature down to a more reasonable 36 degrees. Even the "airless" fan guns require a little compressed air to operate.
Then You Have to Mix It Just Right

So now we have a lot of cold water and a lot of cold air - what's next? There are two sets of pipes running under every slope - over 9 miles of pipe in all. One set distributes air, one set distributes water to over 350+ snowmaking hydrant pairs.

When we are ready to make snow, we connect "snow guns" to the snowmaking stations. The "guns" allow our snowmaking crew to mix just the right amount of air and water to produce snow on the slopes. There are three basic types of snow "guns".

1. Have you noticed the new snowmaking equipment that looks like giant sticks sprouting up around the mountain. Those are high efficiency snow guns. They rely on water pressure to make snow and use much less energy than other types of equipment. The sticks are so tall because it allows the water time to freeze as it drifts back to the slopes as snow.

2. Airless (or fan) guns use a large fan to propel the water into the air to make snow. They only require a very small amount of compressed air to keep things moving. On the front of the gun there is a series of rings with water nozzles on them. As the temperature goes up or down, we can open or close rings to adjust the amount of water we are using.

Most of our airless guns are mounted on towers. The reason is that if we spray the water high into the air, it has more time to fall before it hits the slope. That gives it more time to freeze and dry out. Since we can use more water, we can make more snow. In addition colder/dryer snow is a better surface for skiing and snowboarding too.

3. Air/Water guns rely on compressed air to propel the water through the gun and into the air to make snow. Obviously they use a lot of compressed air to accomplish this. However, since we can adjust both the amount of water and the amount of compressed air very precisely, this system tends to work well in marginal temperatures. However we don't need to use this type of equipment very much anymore.
Doesn't That Waste Water?

First, it is important to note that snowmaking doesn't consume water, it only stores it as snow on our slopes. The water used for snowmaking is surface water that we have stored in our snowmaking ponds. The ponds fill up naturally from rainfall and snow melt. At the end of the season, the snow melts and the water returns to the ponds.

Roundtop Mountain Resort 925 Roundtop Road Lewisberry, PA 17339

Reading Resource 4: How Much Does it Cost to Make Snow at a Ski Resort?

Source:
https://emsenv.com/2016/06/08/cost-to-make-snow/

How Much Does it Cost to Make Snow at a Ski Resort?

June 8, 2016 Allan BlanchardGreen Business Solutions

Do you know how much your resort spends on its snow making process?

We frequently field questions about the cost to make snow, but before we get to the answer, let's review how snow is made. Natural snow is made when a supercooled water droplet condenses around a nucleus of dust or pollen in the sky. Water vapor freezes onto the ice crystal and grows into a snowflake as the flake falls through the atmosphere. Since Mother Nature does not always cooperate with the timing and location of snowstorms, ski resorts have learned to manufacture snow. The basic recipe for manufacturing snow is to combine water and compressed air and spray it out of a tube called a snow gun. In actuality, the process is a lot more complicated. The type of weather, the type of terrain, and the type of technology used to mix water and compressed air all impact the cost to make snow.

Weather

Weather is in a constant state of flux. Weather fronts, daytime heating, and nighttime cooling bring about constant changes. Temperature, humidity, and wind speed are also constantly fluctuating. As such, weather conditions may only be favorable for making snow for a short period of time or sometimes not at all.

Wet Bulb Temperature

The relationship between temperature and humidity is known as the wet bulb temperature. The wet bulb temperature is the lowest temperature that can be reached by evaporating water into the air, and will always be less than or equal to the air temperature. Both temperature and humidity must be low enough for snowmaking. It is possible to make snow with temperatures above freezing, but only when humidity is very low. When humidity is very high, the temperature may have to be several degrees below freezing in order to make snow.

The ability to make quality snow also varies with the wet bulb temperature. If the air is too humid, the moisture on the water droplet will not be readily evaporated, resulting in wet, slushy snow. A wet bulb temperature below 20°F is ideal for producing the desired dry snow.

Wind Speed

The wind can impact snowmaking efficiency in two ways:

1. It directly affects the emergence of snow from the snow gun, giving the snow nuclei more or less hang time. The snow's hang time dictates the size of the snowflakes.
2. It directs the flow of the snow once it exits the gun. If a percentage of the snow lands in the woods or anywhere other than the trails, the cost of snow production increases by that percentage of loss to those non-recoverable locations.

Topography

The topography, the size and shape of the ski trails, the proximity of the hill to water supplies, and the geology all impact the cost for a resort to manufacture snow. Trails with a higher vertical–the change in elevation from the bottom of the trail to the top of the trail–will require a greater effort to pump water to the top than will a trail with a lower vertical. Depending upon the snow gun technology, compressed air lines or electric power lines will also have to be run along the sides of the trails. A ski slope with a very steep pitch may pose difficulties when installing the supply lines and support structures. Depending upon the elevation change and its impact on weather, more snow guns may be required at the lower elevations due to less favorable temperatures that are experienced at higher elevations.

Proximity to Water Supplies

Snowmaking requires a lot of water. Some ski resorts are able to extract water directly from nearby lakes, rivers or streams and pump it up the mountain. Other resorts may have to withdraw the water from more distant sources and stockpile it in ponds more adjacent to the ski hills. The size of the water source, for example a small stream, may limit the water withdrawal rate and water may have to be extracted over an extended period of time to fill the storage ponds. Some ponds are engineered to capture surface runoff so that water is continually reused as the snow melts during the season. There are also often regulatory permitting obstacles for withdrawing the volume of water necessary to operate the ski resort.

Size and Shape of the Trails

The number of snow guns needed for each trail depends largely upon the length and width of the trails. Longer trails need more snow guns in order to provide adequate snow coverage. Wider ski trails may also require more snow guns to provide adequate coverage. Narrow trails require shorter guns. Wide trails require longer guns to cover larger areas more efficiently. Wide open trails may be more impacted by wind than narrower trails and thus may require more of the shorter guns so that snow is not blown away before it reaches the ground.

Geology

In order to prevent freezing of water lines, piping must be run underground. If there is only bare rock and no soil, it may not be possible to bury water lines. In that case, all lines have to be drained between snowmaking events in order to prevent freezing. Installation of platforms and towers for snowmaking equipment may not be possible depending upon the surface and subsurface of the land at the resort.

Technology

There are three main types of snow gun technologies that may be controlled by both manual operators and automation technologies.

Internal-mix Air-Water Snow Guns

Internal-mix air-water guns have a chamber where the water and air are mixed together and forced through an atomizer. The temperature of the water droplets is above freezing as the water/air mixture exits the snow gun. The temperature of the mixture drops rapidly due to evaporation and cooling effects of expansion of the air and the droplets crystallize into snow as they fall to the ground. Traditional internal-mix air-water guns allow continuously variable water-to-fixed-air ratios to adjust to the weather conditions. These guns use a centralized source of compressed air that is piped throughout the resort to the location of the snow guns. These types of guns use the most compressed air and, as a result, have the highest operational costs. **This equipment costs about $5,000.**

External-mix Air-Water Snow Guns

External-mix air-water snow guns, often referred to as low-energy snow guns, use a nozzle to spray water as a fine stream and use separate air nozzles to shoot air through the water stream to break the stream into fine water droplets. Newer guns use internal mixing valves known as nucleators to help create a nucleus for water droplets to bond to as they freeze into snow. These types of guns are usually installed on higher towers to create more hang time for forming snow crystals. Traditional external-mix air-water guns allow continuously variable water-to-fixed-air ratios, but use a lot less compressed air than internal-mix air-water snow guns, especially at lower temperatures. They require a much higher water pressure and utilize much lower air consumption to operate compared to internal-mix guns. External-mix guns cannot overcome strong winds. These guns use a centralized source of compressed air that is piped throughout the resort to the location of the snow guns. **This equipment costs range between $5,000 and $6,000.**

Fan Guns

Fan guns are often referred to as snow cannons or snow fans. Fan guns use on-board compressors and fans to most efficiently create air movement to go with the water. Compressed air and water are sprayed out of the gun through several nozzles and then the airflow generated by a large fan blows the air/water mix as a mist into the air to achieve a long hang time. Fan guns have anywhere from 12 to 360 water nozzles on a ring on the front of the gun through which the fan blows air. The fan guns function well in moderate winds and broadcast snow over large areas. These guns use a centralized source of water, as do all snow guns, however they do not require a centralized source of compressed air as they contain an on-board compressor. By use of an on-board compressor and fan, fan guns use 10-25% of the energy required to operate other types of snow guns. The fan guns do require a source of electricity to operate the on-board compressor and fan so there is an expense of running electricity to each gun. Fan guns are also significantly more expensive than traditional snow guns. **The cost of the fan gun itself may range from $28,000 to $35,000. The towers and platforms needed to mount the fans come with an additional fee. The final cost for installation of snow fans may reach $50,000 apiece.**

Snowmaking Automation

Snowmaking automation can allow ski resorts to take advantage of very small snowmaking windows and also offer opportunities to reduce energy use. Most resorts experience 24-hour periods where wet-bulb temperatures only fall into snowmaking range for a few hours, often associated with nighttime atmospheric cooling. Snowmakers often do not have sufficient time to turn valves and make adjustments to the snowmaking systems during this window. With automation, guns can be started and stopped in a matter of minutes. They can also be controlled to much higher tolerances, enabling the automated system to consume significantly less compressed air and produce better quality snow under varying weather conditions. Automation also reduces manpower requirements and associated potential exposure to injury.

As ideal temperature windows are shortened due to annual rising temperatures, automated snowmaking systems allow for the production of snow when conditions are optimal. Automated systems can adjust individual guns to temperature, humidity, and even fluctuating wind speeds.

As you can imagine, there are many possibilities for automation, and costs can be highly variable depending on configurations and selected features.

Advantages of automated controls

- The likelihood that snowmaking needs to start before or extend beyond non-peak times is reduced.
- Startup tuning period reduces the need for ongoing operator intervention.
- The equipment does not need to operate in standby mode while guns and fans are manually tuned for full production.
- Sub-optimal motor and pump operating conditions, which are electrically inefficient while system is only partially producing, are reduced.
- Ability to turn multiple delivery units off or on as a group.
- Remote control of individual delivery units is available, reducing startup and standby times.

So How Much Does it Cost to Make Snow?

The cost to make snow is highly dependent upon the weather, the terrain and the technology. **Based upon our experience, our client's costs to make snow (depending mainly upon snow gun selection and to a lesser extent upon weather) have ranged from $70 to $2,100 per acre-foot including electric, pressurized water delivery and compressed air delivery to each snow gun.**

There is no one particular snow gun or automation technology that is perfect for every resort. Various gun technologies deliver performance at different wet bulb temperatures, different wind conditions, and different trail and elevation configurations. Some resorts already have certain infrastructure in place such that may not be economically feasible to switch to certain technologies. However, every resort we have studied has realized tremendous energy savings by replacing some of their outdated snowmaking equipment.

Many of our clients had no idea of the **up to five-fold difference in relative energy consumption costs** between the different technologies or the cost-benefits that could be realized through automation. The good news is there are also opportunities for electric utility rebates for making energy efficient investments in new snowmaking technology!

Reading Resource 5: Cost of Snow-making
Source:

https://adventure.howstuffworks.com/outdoor-activities/snow-sports/snow-maker6.htm

Costs of Snowmaking

To cover several ski trails with man made snow, you need *a lot* of water. According to SMI Snow Makers, it takes about 75,000 gallons (285,000 liters) of water to create a 6-inch blanket of snow covering a 200x200-foot area (61x61 meters). The system in a good-sized ski slope can convert 5,000 to 10,000 gallons (18,927 to 37,854 liters) of water to snow every minute!

Water is not a huge expense for ski resorts, however; and pumping this much water isn't incredibly bad for the environment. Most resorts pump water from one or more reservoirs located in low-lying areas. The run-off water from the slopes feeds back into these reservoirs, so the resort can actually use the same water over and over again. Moving this water around can have some negative effects on plant and animal life, though, so ski slopes must work hard to keep water levels fairly balanced.

A significant environmental concern, and one of a resort's biggest expenses, is **power consumption**. If a slope uses compressed air in its snow guns, it has to provide a lot of energy to run the large air-compressing pumps. It also needs a pump system to provide the water to the snow makers. These pumps are often run by diesel engines, which expel a high level of air pollution.

Ski resorts that use airless snow guns also need a good amount of power to run the machines' fans. These types of snow guns consume a lot less energy for every foot of snow they produce, but they are still major power draws. For most ski resorts, power consumption is the second biggest operating expense, just behind labor costs (snow-making alone requires a lot of manpower). No matter what sort of technology a resort uses, snow-making accounts for a high percentage of this power use.

Because of the expense of making snow, ski resorts have to develop a good strategy for when and where they are going to use their machines. A lot of the work involved in snow-making is the task of balancing the cost of running the machines with the benefits of extending the ski season. Efficient snow-makers make sure they don't waste power making snow where it won't do any good, and they are very careful to make snow only when it will stick around.

As we've seen, snow-makers have to take many variables into account to cover a slope with ideal skiing snow. The idea behind man made snow is extremely simple; but actually getting it to work effectively is quite a feat. Many snow-makers describe the job as a challenging marriage of science and art -- the basic elements are precise weather measurements and expensive machinery, but you need instinct, improvisation and creativity to get it exactly right.

Snowmaking Science

Two of the Most Important Variables in Making Snow are:

1. Temperature & Humidity - The relationship between temperature and humidity is called Wet bulb Temperature.
   Both Temperature and Humidity must be low enough for Snowmaking. Click here to find a live snowmaking weather tool that will give you the current snowmaking conditions where you live. This tool will also give you your snowmaking forecast and snow making history (*how many days you could have made snow last year*). On the weather tool page you will also find a snowmaking weather chart you can print out to determine if the temperature and humidity are right for you to make snow. This chart also shows Wet bulb temperature. (definition found below)

2. Water temperature, very simply put the colder the better. Commercial snow makers at ski areas typically use water from ponds, this water temperature is usually from 34 to 40 deg. Fahrenheit. Our Snowmakers are designed specifically to be used with household water supply which is typically 15 to 25 degrees Fahrenheit warmer than commercial water supply for ski areas.

How does it work? (The Quick Explanation):

The science of snowmaking can be quite complex. For the majority of us, however, a simple explanation of how the different parts of a snowmaker act will suffice. Snowmaking in its simplest form is the act of turning water into small ice crystals (snow). In order to make snow from your home water supply (at about 50°F), it must be cooled very rapidly.

Four things come into play to make this happen: *ambient temperatures, evaporation, surface area, super cooling.*

Ambient Temperature

First it must be cold outside. Even when the outdoor temperature is below freezing (32°F) snow quality can be poor or slushy. This is because much of the water is not staying or even turning into the frozen state. If you refer to our snowmaking weather chart, you will see what the ideal temperatures are for snow making.

Evaporation

The second factor is heat loss through evaporation. As some of the water evaporates from the surface of the drop a small amount of heat is removed from the drop itself. Try putting some rubbing alcohol on your arm. As it evaporates you will experience this cooling effect. Your body uses this process of evaporation to cool itself, we call it sweating. When the air is humid, there is already a lot of moisture in the air. Your sweat is less readily absorbed into the air and is unable to evaporate from your skin removing the heat with it. The same premise happens in snowmaking. When there is high humidity, the water droplet's surface is not able to evaporate a small amount of water and remove some of the heat. Therefore, in snowmaking we must refer to the "Wet Bulb Temperature". This is a measure of the ambient temperature that takes into account the cooling effect the humidity in the air allows for.

Surface Area

The third way we cool the water is by increasing the surface area of the drop. By increasing the surface area, we expose as much of the water to the cold as possible. The smaller we make these drops, the greater the surface area to volume ratio. We achieve the proper drop size and spray pattern through our highly specialized nozzles. And yes, the nozzles do matter! In order to optimize the size of the droplets, the distance between the drops, and the water volume flowing through the opening while employing high pressures to achieve proper distance and hang time, we engineered nozzles specifically for snowmaking.

Super Cooling

Finally we need to look at supercooling. When a compressed gas (in this case air) is allowed to rapidly expand, there is a decrease in temperature. This is known as the Joule-Thomson Effect. The conditions at the air nozzle are such that the mist coming from the nucleation nozzle is able to immediately freeze. These tiny ice crystals are then drafted into the larger upper mists which seed and snap the pre-cooled water droplets into a frozen state. The result is snow that then falls out of the mist.

The Science of Snow Making by:

Heat Exchange Process

Snowmaking is a heat exchange process. Heat is removed from snowmaking water by evaporative and convective cooling and released into the surrounding environment. This heat creates a micro-climate inside the snowmaking plume that is very different from ambient conditions. Understanding this process can lead to practical benefits to the snowmaker.

There are many variables that affect snowmaking. Three of the most important variables are wet bulb temperature, nucleation temperature and droplet size.

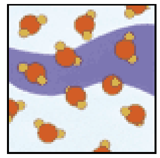
Wet Bulb Temperature

The temperature of a water droplet exiting a snow gun is typically between 34 F and 44 F. Once a water droplet passes the nozzle and is released into the air, its temperature falls rapidly due to expansive and convective cooling and evaporative effects. The droplet's temperature will continue to fall until equilibrium is reached. This is the wet bulb temperature and it is as important as dry bulb (ambient) temperature in predicting snowmaking success. For example, snowmaking temperatures at 28 F and 10% humidity are equivalent to those at 20 F and 90% humidity.

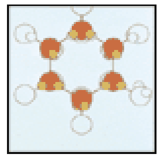
Nucleation Temperature

Once the wet bulb temperature is know, there must be a way to predict whether water droplets will actually freeze at that temperature.

Ice is the result of a liquid (water) becoming a solid (ice) by an event called nucleation. A water droplet must first reach its nucleation temperature to freeze. there are two types of nucleation, homogeneous nucleation and heterogeneous nucleation.



Water Molecules in Liquid Form



(Solid Form) Molecules Form A Hexagonal Array

Homogeneous Nucleation

Homogeneous nucleation occurs in pure water with no contact with any other foreign substance or surface. With homogeneous nucleation, the conversion of the liquid state to solid state is done by either lowering temperatures or by changes in pressure. However, the primary influence on the conversion of water to ice or ice to water is temperature.

In homogeneous nucleation, the nucleation begins when a very small volume of water molecules reaches the solid state. This small volume of water molecules reaches the solid state. This small volume of molecules is called the embryo and becomes the basis for further growth until all of the water is converted. the growth process is controlled by the rate of removal of the latent heat being released. Molecules are attaching and detaching from the embryo at roughly equal and very rapid rates. As more molecules attach to the embryo, energy is released causing the temperature of the attached molecules to be lower than the temperature of the unattached molecules. The growth rate continues until all the molecules are attached. At this point, you have the solid state (ice).

Most of us would think pure water freezes at 0 C or 32 F. In fact, the nucleation event (freezing) for pure water will take place as low as minus 40 C or minus 40 F. This is mostly likely to occur in laboratory experiments or high in the upper atmosphere (upper troposphere).

Heterogeneous Nucleation

The heterogeneous nucleation process is when ice forms at temperatures above minus 40 C or minus 40 F due to the presence of a foreign material in the water. this foreign material acts as the embryo and grows more rapidly than embryos of pure water. The location on which an ice embryo is formed is called an ice-nucleating site. As with homogeneous nucleation, heterogeneous nucleation is governed by two major factors: the free energy change involved in forming the embryo and the dynamic of fluctuating embryo growth. In heterogeneous nucleation, the configuration and energy of interaction at the nucleating site become the dominating influence in the conversion of water to ice. Snowmaking involves the process of heterogeneous nucleation.

There are many materials and substances which act as nucleates, each promotes freezing at a specific temperature or nucleation temperature. they are generally categorized as high-temperature (i.e., sliver iodide, dry ice and ice nucleating proteins) or low-temperature (i.e., calcium, magnesium, dust and silt) nucleates. It is the low-temperature nucleators that are found in large numbers in untreated snowmaking water. the nucleation temperature of snowmaking water is between 15 F and 20F.

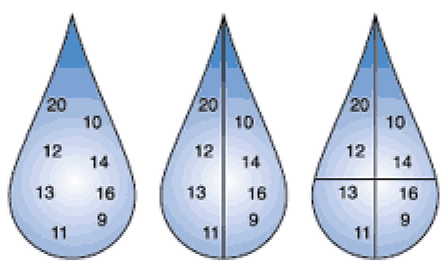
But wait a minute! Why do you hear freezing warnings at temperatures around 32 F? The answer is that another factor is coming into play with the freezing process. That factor is called surface (i.e., roads, highways, trees). There is an energy interaction between the ice-nucleating site in the water with the surface. This causes the water droplets to freeze very near 32 F or 0 C.

In snowmaking it is the nucleator having the highest nucleation temperature that determines when a water droplet will freeze.

As a water droplet cools, heat energy is released into the atmosphere at a rate of one calorie per gram of water. As it freezes into an ice crystal, the water droplet will release additional energy at a rate of 80 calories per gram of water. This quick release of energy raises the water droplet temperature to 32 F, where it will remain while freezing continues. This is one reason why we are accustomed to thinking that water freezes at 32 F. To be precise, the water will continue to freeze as long as it remains at or below 32 F, but only after it has first cooled to its nucleation temperature. Any excess energy will be dissipated into the atmosphere.

Droplet Size

Since the distribution of various nucleators in a given volume of water is totally random, the size of the water droplet or the number of high-temperature nucleators has a significant effect on the temperature at which freezing occurs (nucleation temperature). In natural water, as the size of the water droplet decrease, the likelihood that the droplet will contain a high-temperature nucleator also decreases. Conversely, larger water droplets stand a better chance of containing high-temperature nucleators. The optimum situation for snowmakers is one where each and every droplet of water passing through the snow gun nozzle contains at least one high-temperature nucleator and where each droplet freezes in the plume.



Numbers in the droplets represent various ice-nucleating sites with different nucleation temperatures. The highest number nucleator in the droplet will determine at what temperature the water droplet will freeze.

The relationship between the variables of nucleation temperature and droplet size is summarized in two statistically valid conclusions. Firstly, a 50% increase in the droplet size results in a one-degree F increase in nucleation temperature. Secondly, a 50% decrease in droplet size results in a three-degree F decrease in nucleation temperature. These conclusions are based on an average droplet size can by counter-productive to promoting high-temperature nucleation, unless enough high-temperature nucleators are present to compensate.

Looking at the relationship between droplet size and evaporation, research in cloud seeding show that:

These conclusions further point out the undesirable results from using very small droplets, especially in areas where water loss is a critical issue.

Relating droplets size to nucleation temperature, it is possible to increase snowmaking production and efficiency by using high-temperature nucleators together with larger water droplets. this frequently not only allows increased water flow, but also reduces evaporation and yields more snow on the ground. In fact, studies indicate that a 20% increase in water flow can increase snow volume up to 40% if droplet size and nucleation temperature is optimized.

In conclusion, a better understanding of the dynamics between wet bulb temperatures; nucleation temperature and droplet size together with a practical application of the science involved can help improve the efficiency of the snow manufacturing process.

Reading Resource 6: The Science Behind Snowmaking
Source: Robert Pursell, Men's Journal 2019

Snow guns.

Most anyone who has ever gone skiing or snowboarding has seen them endlessly blasting away on the sides of a trail, coating ski slopes in man-made snow.

And while many seasoned riders can talk your ear off about how man-made snow is heavier, wetter and lacking in that indescribable "pow" quotient that natural snow has, you'd be hard pressed to find a skier or snowboarder who doesn't see the value the man-made white stuff provides.

The image on the left is a close-up of natural snow. The one on the right is man-made. So it turns out there is merit to the notion that natural snow is better. Photo: Courtesy of NASA

There's a whole bunch of science behind freezing water and shooting it into the air. Photo: Courtesy of John Lemieux/Flickr

But does anyone really understand how snowmaking works? How is it snow guns are able to blow snow when the weather doesn't otherwise permit the formation of those beautiful frozen water crystals? Is it wizardry?

To answer these questions we called Robin Smith, the general manager for TechnoAlpin — the world's largest snowmaking company. Here's what he had to say:

So, explaining it to somebody with an almost nonexistent grasp on science, how is snow made?

There's two basic systems of making snow.

In the industry, one of the methods is called "air-water." Those are basically the snow guns you see mounted on the side of trails that look like 50 caliber machine guns.

In that system, small frozen droplets of water are shot out into the atmosphere using highly pressurized water and air, and as they're leaving the gun the droplets become "snow flakes" by attaching to particles of dirt in the atmosphere — those particles are known as seed nuclei.

In the other system, which uses fans to spread the snow, the snow flakes are made by a compressor inside each machine.

In those, the frozen particles are attached to the seed nuclei — which are only about 20 microns wide — in the snowmaker and then distributed by a large fan.

Generally speaking, the fan systems distribute the snow the furthest and are better for wide trails while the air water guns are better for narrow trails.

Fan systems are better for covering wide swaths of ski slopes in the white stuff. Photo: Courtesy of Sugarloaf

So then how is it that snow guns can operate in temperatures above freezing?

Well, the reality is that traditional snowmaking machines *can't* operate above freezing, it just seems that way to you because of the temperature you are reading. Snow guns can only operate if it's 28 degrees Fahrenheit *wet-bulb* or lower.

Traditionally, people read a thermometer, and maybe it will say it's 30 degrees Fahrenheit outside. That's well and good, but that reading doesn't take into account humidity. A wet-bulb reading is a more accurate reading as it measures 100 percent relative humidity in the area.

So in other words, your car thermometer might say it's 40 degrees, but if you're in a place like Colorado, where the air is very dry and the atmosphere isn't already saturated with water, the wet-bulb temperature might be 14 or 16 degrees, so it appears they're making snow above freezing.

But on the East Coast, where there's a lot of humidity in the air, the wet-bulb temperature will look more akin to the traditional thermostat you're reading.

The Snow Factory (above) is capable of producing snow at temperatures above 60 degrees. Photo: Courtesy of TechnoAlpin

So one of the reasons we called you is because of your Snow Factory system. We wrote about how it's a new system that allowed Boreal Mountain Resort up in Lake Tahoe to blow snow through July. How does that work?

Snowmaking, I believe, began in the 1950s when a farmer invented a spray rig in an attempt to freeze proof his apple orchard, but instead of water what came out was more like snow. And there haven't been a whole bunch of advances in it since then.

What we do with the Snow Factory is much simpler than that: We basically construct the biggest ice making machine you've ever seen, like what would be behind a bar, but the size of a shipping container.

But instead of cubed ice we make flaked ice, in pieces thinner then a dime, and where an ice cube simply needs to be frozen, ours are frozen to an extremely low temperature, which makes them more resistant to thawing.

And surprisingly, when a cat goes over our stuff it's much different than normal man-made snow. It skis much better.

Originally we thought that 60-65 degrees Fahrenheit would be the highest reaches of what we could produce our snow at, but Boreal was making it up to 90 degrees. A lot of it was melting, but our snow allowed them to keep one rail park run open through July.

While the thought of being able to blow snow year-round might sound tempting to snow deprived resorts, the chances of that are slim. Photo: Courtesy of Kris Arnold/Flickr

So does that mean that, with this new technology, we can expect to see more resorts staying open year-round?

Unfortunately, that's not too likely.

One Snow Factory on its own won't produce enough snow to maintain an entire ski run, at least not well enough. It has about the same production as one of the fan systems running at marginal temperatures, but a Snow Factory's energy consumption is four times that of a normal snow gun.

So to attempt to keep an entire resort open year round using only Snow Factories would be really inefficient.

However, if you were to strategically implement Snow Factories in ski resorts that already have traditional snow guns and the temperatures for conventional snowmaking, you could prolong a ski season pretty far.