Introduction

Formative Assessment Exemplar - CHEM.3.1

Introduction:

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

Of note: All formative assessment clusters were revised based on feedback from educators after being utilized in the classroom. During the revision process, each cluster was specifically checked to make sure the phenomena was authentic to the DCI, supporting information was provided for the phenomena, the SEPs, CCCs, and DCIs were appropriate for the learning progressions, the cluster supported student sensemaking through the Gather, Reason, and Communicate instructional model, and the final communication prompt aligned with the cluster phenomena. As inconsistencies were found, revisions were made to support student sensemaking. If other inconsistencies exist that need to be addressed, please email the current Utah State Science Education Specialists with feedback.

General Format:

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

Accommodation Considerations:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

References:

Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

Teacher Facing Info

Teacher Facing Information

Standard: CHEM.3.1

Assessment Format: Printable or Online Format (Does not require students to have online access)

<table>
<tr><th colspan="2">Phenomenon</th></tr>
<tr><td>At an outdoor party with some friends, one of the activities is to make homemade ice cream. To do this, you add the ice cream ingredients of cream and sugar into a small can with a lid. This small can is placed in a larger container that is filled with table salt and ice. You and your friends aren’t sure on the right salt to ice ratio, so you guys decide to break into groups and test out different salt to ice ratios.</td><td>Proficient Student Explanation of Phenomenon:

The salt acts as a solute in the salt-ice solution. By adding more salt, the freezing point of the ice drops. The salt to ice ratio is important in determining freezing point. This causes the cream to freeze and form ice cream.</td></tr>
<tr><th colspan="2">Cluster Task Statement</th></tr>
<tr><td colspan="2">(Represents the ultimate way the phenomenon will be explained or the design problem will be addressed)

In the questions that follow, you will explain how the proportional ratio of salt to ice affects the ice cream making process.</td></tr>
<tr><th colspan="2">Supporting Information</th></tr>
<tr><td colspan="2">Cluster Task Statement: (Represents the ultimate way the phenomenon will be explained or the design problem will be addressed)

Figure 1: Making Homemade Ice Cream</td></tr>
</table>

Photo from Flickr by Nick Normal

Table 1: Data from ice cream making

	Salt (NaCl) mass (g)	Ice mass (g)	Minimum Temperature of the Salt-Ice Mix (°C)	Ice cream Consistency
Group 1	30 g	500 g	-3.8 °C	Cold liquid
Group 2	50 g	500 g	-6.4 °C	Soft ice cream
Group 3	100 g	1000 g	-6.5 °C	Soft ice cream
Group 4	350 g	1000 g	-20.0 °C	Hard ice cream

Reading 1- Why Does Salt Melt Ice?
Adapted from Grannan, Cydney. "Why Does Salt Melt Ice?". Encyclopedia Britannica, 24 Aug. 2016, https://www.britannica.com/story/why-does-salt-melt-ice. Accessed 27 February 2023.

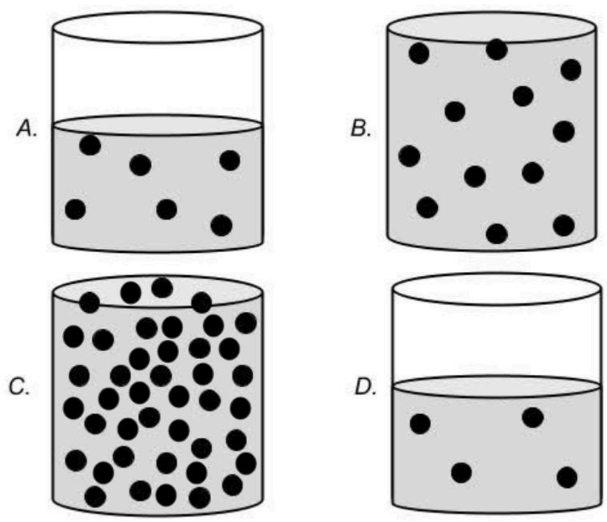
Each year, more than 20 million tons of salt are spread on snowy and icy roads in cold northern areas to help melt the ice. But how does salt cause ice to melt? Let's start by talking about water in the winter. When the temperature drops to 32 degrees Fahrenheit (0 degrees Celsius), water turns into ice. At this point, icy roads have a thin layer of water on top of the ice, and the water and ice molecules interact. Some of the water is melting the ice, while the ice is also freezing some of the water. At this temperature, the exchange rate is constant, meaning the amount of water and ice stays the same. If it gets colder, more water turns into ice; if it gets warmer, more ice becomes water.

Now, when salt is added to the mix, it lowers the freezing point of the water. This means that the ice on the ground can't freeze the layer of water at 32 °F anymore. The water, however, can still melt the

ice at that temperature, resulting in less ice on the roads. But you may be asking how salt lowers the freezing point of water. This concept is called “freezing point depression.” Essentially, the salt makes it harder for the water molecules to bond together in their rigid structure. In water, salt is a solute that will break into its elements. So, if you’re using table salt, also known as sodium chloride (NaCl), to melt ice, the salt will dissolve into separate sodium ions and chloride ions. Often, however, cities use calcium chloride ($CaCl_2$), another type of salt, on their icy streets. Calcium chloride is more effective at melting ice because it can break down into three ions instead of two: one calcium ion and two chloride ions. More ions mean more ions getting in the way of those rigid ice (hydrogen) bonds.

Cluster Questions	
Gather Cluster Question #___1___ Question Type: MC Addresses: __x__ DCI (PS1.A) __x__ SEP Computational Thinking __x__ CCC patterns, proportion Answer: A	Question 1: According to the data from Table 1, what is the main factor that affects the temperature of the salt-ice mixture? a. The ratio of salt to ice b. The amount of ice c. The amount of salt d. There is no correlation between ice and salt and the temperature
Gather: Cluster Question #___2___ Question Type: MC Addresses: _____ DCI __x__ SEP mathematical and computational thinking __x__ CCC proportion Answer: D	Question 2: Which group’s salt-ice mixture reported in Table 1 has the highest concentration NaCl? a. Group 1 b. Group 2 c. Group 3 d. Group 4
Reason: Cluster Question #___3___ Question Type: Matching Addresses: __x__ DCI (PS1.A) __x__ SEP Models __x__ CCC Proportion and Quantity Answer: Group 1 - D Group 2 - A	Question 3: Match the models below to the salt-ice solution each group made (Table 1) when making ice cream. Salt is represented by black circles and water molecules are the gray shaded portion in the drawing.

Group 3 - B
Group 4- C



Group 1: __________
Group 2: ___________
Group 3: ___________
Group 4: ___________

Reason:
Cluster Question #_4_____
Question Type: MC
Addresses:
__x__ DCI (PS1.A)
__x__ SEP Mathematical Thinking
__x__ CCC Proportion
Answer: C

Question 4:

A fifth group joined the activity. If the group used approximately 1000 grams of ice and wanted to reach a temperature of about -13^{o}C, how much salt should they use?

a. 50 grams
b. 115 grams
c. 225 grams
d. 300 grams

Communicate:
Cluster Question #___5___
Question Type: LA
Addresses:
__x__ DCI(PS1.A)
__x__ SEP Constructing Explanation
__x__ CCC Cause and Effect, patterns

Answer: The ice cream consistency would be between soft and hard. The salt acts as a solute in the salt-ice solution. By

Question 5:

Based on the previous question, assume group 5 reached a temperature of -13 ^{o}C.
1) Predict the ice cream consistency using patterns from **Table 1**.
2) Using **Reading 1**, explain what causes the freezing point in ice to lower when you add salt. Explain how the salt-ice ratio causes ice cream to freeze at different consistencies.

	Salt Mass (g)	Ice Mass (g)	Minimum Temperature of the Salt-Ice Mix (^{o}C)	Ice Cream Consistency

adding more salt compared to solvent (higher ratio), the freezing point of the ice drops more. The salt to ice ratio is important in determining freezing point. This causes the cream to freeze and form ice cream.	<table><tr><td>Group 5</td><td>?</td><td>1000 grams</td><td>-13° C</td><td>?</td></tr></table>

Proficiency Scale

Proficient Student Explanation:

The salt acts as a solute in the salt-ice solution. By adding more salt, the freezing point of the ice drops. The salt to ice ratio is important in determining freezing point. This causes the cream to freeze and form ice cream.

Level 1 - Emerging	Level 2 - Partially Proficient	Level 3 - Proficient	Level 4 - Extending
SEP: Does not meet the minimum standard to receive a 2.	**SEP:** Use mathematical representations to describe and/or support scientific conclusions and design solutions. Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.	**SEP:** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).	**SEP:** Extends beyond proficient in any way.
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Observes phenomena at one scale may not be observable at another scale. Recognizes that the observed function of	**CCC:** Recognizes that patterns that are observable at one scale may not be observable or exist at other scales.	**CCC:** Extends beyond proficient in any way.

	natural and designed systems may change with scale and that proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.	Uses algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).	
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** Each pure substance has characteristic physical and chemical properties. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In solids, particles have little motion.	**DCI:** Substances may combine to form a solution (a uniform mixture). The properties of the solution depend on the concentration of solute in the solution.	**DCI:** Extends beyond proficient in any way.

(Student Facing Format on following page)

Student Assessment

Name: ____ Date: ________

Stimulus

At an outdoor party with some friends, one of the activities is to make homemade ice cream. To do this, you add the ice cream ingredients of cream and sugar into a small can with a lid. This small can is placed in a larger container that is filled with table salt and ice. You and your friends aren't sure about the right salt to ice ratio, so you decide to break into groups and test out different salt to ice ratios.

Figure 1: Making Homemade Ice Cream

Table 1- Data from ice cream making

	Salt (NaCl) mass (g)	Ice mass (g)	Minimum Temperature of the Salt-Ice Mix (°C)	Ice cream Consistency
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Now, when salt is added to the mix, it lowers the freezing point of the water. This means that the ice on the ground can't freeze the layer of water at 32 °F anymore. The water, however, can still melt the ice at that temperature, resulting in less ice on the roads.

But you may be asking how salt lowers the freezing point of water. This concept is called "freezing point depression." Essentially, the salt makes it harder for the water molecules to bond together in their rigid structure. In water, salt is a solute that will break into its elements. So, if you're using table salt, also known as sodium chloride (NaCl), to melt ice, the salt will dissolve into separate sodium ions and chloride ions. Often, however, cities use calcium chloride ($CaCl_2$), another type of salt, on their icy streets. Calcium chloride is more effective at melting ice because it can break down into three ions instead of two: one calcium ion and two chloride ions. More ions mean more ions getting in the way of those rigid ice (hydrogen) bonds.

Your Task

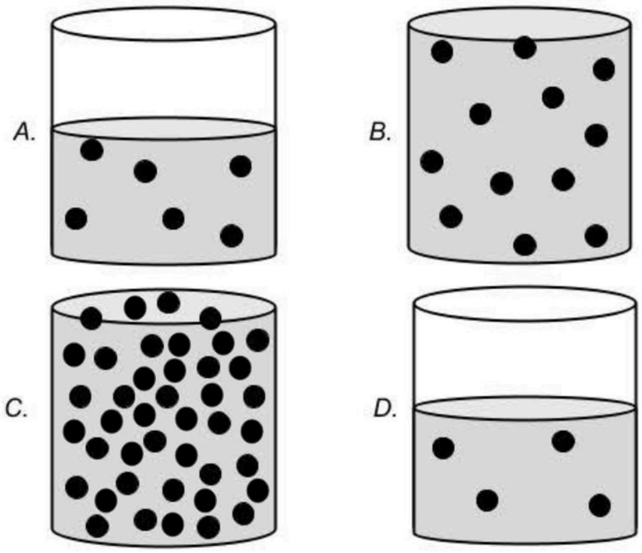
In the questions that follow, you will explain how the proportional ratio of salt to ice affects the ice cream making process.

Question 1
According to the data from **Table 1**, what is the main factor that affects the temperature of the salt-ice mixture?
a. The ratio of salt to ice
b. The amount of ice
c. The amount of salt
d. There is no correlation between ice and salt and the temperature

Question 2
Which group's salt-ice mixture reported in **Table 1** has the highest concentration NaCl?
a. Group 1
b. Group 2
c. Group 3
d. Group 4

Question 3

Match the models below to the salt-ice solution each group made (Table 1) when making ice cream. Salt is represented by black circles and water molecules are the gray shaded portion in the drawing.



Group 1: ___________

Group 2: ____________

Group 3: ____________

Group 4: ____________

Question 4

A fifth group joined the activity. If the group used approximately 1000 grams of ice and wanted to reach a temperature of about -13°C, how much salt should they use?

a. 50 grams
b. 115 grams
c. 225 grams
d. 300 grams

Question 5

Based on the previous question, assume group 5 reached a temperature of -13 °C.

1) Predict Group 5's ice cream consistency using patterns from **Table 1**.
2) Use **Reading 1** as evidence to explain what causes the freezing point in ice cream to lower when you add salt.
3) Explain how the salt-ice ratio causes ice cream to freeze at different consistencies.

	Salt Mass (g)	Ice Mass (g)	Minimum Temperature of the Salt-Ice Mix (°C)	Ice Cream Consistency
Group 5	?	1000 grams	-13° C	?