Pattern Analysis of Student Thinking (PAST)
MS-PS1-4: Energy and States of Matter Ice Fumaroles Assessment Task

PE - Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

DCI – Structure and Properties of Matter:

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. 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 a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

Definitions of Energy: (secondary to MS-PS1-4)

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.

TASK 1 – *Develop and use a model to explain transfer of thermal energy*

Purpose	Student Response Themes	Examples of Student Responses	Possible Teacher Instructional Moves
The first task asks students to develop a basic model of the system from a written explanation of the phenomenon. Students need to make sense of the system before they can develop explanations for where and why particles are moving among parts of it.	Detailed model with correct labels and temperatures.	N/A	• Show images or video of an actual fumarole and cave or a diagram of the system structure. (Search for Mt. Erebus ice fumaroles or ice caves.) • Draw the fumarole, cave, and volcano part of the system as a group; then ask students to complete the model.

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This section of the task asks students to connect changes in particle motion that occur as particles move between parts of the system with significantly different temperatures. The final task builds on the particle motion scaffold from the previous task. It requires students to apply the knowledge that temperature is a measurement of thermal energy to make sense of phase changes using their system model. Students should be able to explain and model how transfer of thermal energy (indicated by temperature differences within the system) causes the phase changes that cause ice fumaroles to form.	• The gas particles change temperature when they leave the cave • Particles in warm air move more quickly, spread out, and become less dense • Gas particles transfer their energy to the cold air	• *As the cold air freezes the gas particles outside of the ice cave, the gas particles transfer their energy to the cold air.* • *When the gas is freed the atoms go nuts and they move really fast.* • *When the particles go into warmer climates the particles move away from one another and become more spread out into the air.*	• If students leave out particle motion or mix up the direction of energy transfer, use a demonstration or video showing particle motion in different temperatures (e.g., dispersal of food coloring in water). Discuss *why* particles move differently in different states of matter. • The teacher could model how to visually represent particles of matter. • Videos of the Mpemba effect might help students conceptualize how steam could freeze in a way that allows ice/snow to build up. *(Note: The Mpemba effect is not well understood by scientists. It should only be used as a visual rather than an explanation.)*
Focus SEP/CCC: Students are developing and using a model to describe how the cause and effect relationship between particle motion and thermal energy helps form ice fumaroles.			

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TASK 2 – *Use data to predict fumarole change over time*			
Purpose	**Student Response Themes**	**Examples of Student Responses**	**Possible Teacher Instructional Moves**
In Task 2, students are synthesizing relationships among the ideas developed in the previous task. They should be able to explain how changes in particle speed lead to phase changes. Students should also be able to model specifically where transfers of thermal energy cause the observed phase changes. Without the addition of thermal energy to the system, students should conclude that ice fumarole growth will slow down and/or stop. Answers that discuss eruption/explosion of the volcano are not wrong, but they do miss the point.	The fumarole stops growing and eventually breaks.	*The fumarole would discontinue to grow and would melt completely over time.*	See Task 1
	Volcanic gases will find or make a new crack to build a fumarole somewhere else.	*If the gas got trapped it would run out of space and make a hole and start to form another ice fumarole.*	
	Pressure will build up since gas can't escape and it will cause an explosion.	*If the cracks get sealed that will create pressure and explode the volcano.*	
Focus SEP/CCC: Students use a model to predict growth of ice fumaroles due to changes in particle motion caused by thermal energy transfer within the system.			

K20CENTER THE UNIVERSITY OF OKLAHOMA
Noble Public Schools
OSDE
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