Causal Patterns in Science
a professional development resource

Galileo's Thermometer Task

Assessing Understanding

Show the students the Galileo's thermometer. How do they think it works? Turn on a heat source near the thermometer. What do they notice? What is going on and why?
Explain that there is liquid inside the glass tube. There are also little glass balls. Each of the balls in the thermometer is filled with a different-colored liquid and has a metal tag hanging from the bottom. The balls rise and sink as the temperature changes. You can tell the temperature outside by reading the tag that hangs from the bottom ball in the top group of balls (the tags that hang from the balls have certain temperatures written on them). Ask the students to draw a model and give a written explanation of how Galileo's thermometer works, that is, explain how the balls move. Also ask students to explain WHY what happens happens, in as much detail as possible. Give them at least 15 minutes to think about the problem individually. Then ask them to have a conversation with a couple of students around them to try to figure out how it works. Listen carefully to the kinds of comments that the students make.

Why is "How a Galileo's Thermometer Works" a Good Open-Ended Assessment Question?

There are many different levels upon which to analyze a Galileo's thermometer and a lot of possible answers for what is going on. The answer to the problem is not immediately apparent and students need to figure out which variables are relevant and which are not. It draws considerably on their knowledge of density, volume, mass, and changes with increases in temperature. Think about the problem for a moment.

You have liquid in the tube that changes density as it changes temperature. There is liquid in each glass ball that also changes density as it changes temperature.

However, the balls are closed systems, so students need to consider what that means. It is not clear if the liquid in each ball is the same or different than that of the other balls, but it is a different color and the coloring might make a little difference due to the pigmentation. Each glass ball has a metal tag. The tags look a little different from each other.

These variables invite students to consider the question on many different levels and to consider many different possible explanations for what is going on. Students will discuss and consider the different variables, perhaps ruling out some and including others. They will need to consider what they do and don't know. In some cases, they won't know what they know for sure and will need to reason about hypothetical situations. ("If the density of the balls could change…")

The question invites students to reason about different relationships—the relationship of the glass balls with metal tags to the liquid in the tube, the mass of the metal tag in relation to the space it takes up, the liquid and unfilled parts inside the glass balls in relation to the volume of the glass balls in relation to the liquid in the larger tube, and so on. Students who are really thinking about the problem will consider relationships within relationships and will consider them dynamically as the temperature changes.

What Kinds of Things Might Students Say?

"The temperature outside changes."
"The liquid in the tube can change density."
"Those metal medallions could change density."
"Can just one ball change density?"
"It doesn't matter what else is happening. All that has to happen is that the balls with the tags change density."
"It has to do with how crowded the particles in the tube are, too."
"I think that the density of the liquid in the tube will change but so will the density of the liquid in the balls and that makes it constant…. Hmmm… unless the temperature makes some liquids spread out more than others"
"But we don't know if the liquids in the balls are the same or different. They could just be different colors…"
"Why would they make the balls different colors if it doesn't matter?"
"Wait, but how can the density in the balls change if the amount of liquid is always the same and the volume can't change because the ball is closed up?"
"I don't know, could it, if this space didn't have air in it? But no, the overall space is still as big as the glass ball only."
"What about the metal part? Does metal change density when it gets heated?"
"But if the metal does change density and the liquid in the tube changes density, why would the balls move?"
"Which changes density more, metal or liquid?"
"Let's make a dots-per-box model to show what might change and how…"

What Really is Going On?

The real answer to this question is that it doesn't matter—at least not in terms of its value as an assessment question: what is important in this type of assessment is not whether the students get the correct answer, but how students are thinking and reasoning about the problem at hand. That said, this activity is a great way to push students to extend what they have learned about relational causality in density. In terms of the science, here's what appears to be going on. (What is really going on may depend upon the particular thermometer and different thermometers come with different explanations. But the typical explanation is as follows.) It is the differences in the metal medallions that account for the differences in density between the glass balls. It is not clear if the liquid in the balls is different. The density of the glass part of the cruets can be considered constant. As the temperature changes, the density of the liquid in the glass tube and the density of the metal tags are affected and some glass balls rise while others fall. This makes the relationship between the densities dynamic.