Talk Science

Professional Development

Transcript for Grade 4 Scientist Case: The Heavy for Size Investigations

1. The Heavy for Size Investigations, Through the Eyes of a Scientist

We met Associate Professor Chris Swan in the soil laboratory at Tufts University and asked him to do some of the same investigations that your students do in the Heavy for Size section of the 4th grade Inquiry Project curriculum. Your students compare the weights of samples of sand, organic soil, water, and oil. Although the volumes are the same, the weights of the different materials are not the same. We call the relationship between weight and volume, "heaviness for size."

Heaviness for size lays the foundation for the important property of density introduced in middle school. Density is one of the core concepts of the Inquiry curriculum. Density can't be measured directly. It's the ratio of two quantities that can be measured: weight (or mass) and volume. Every material has a characteristic density that is the same, no matter how big the sample. In his own research, Chris finds the density of soils and of new materials made from recycled material. Density gives Chris clues about other important properties such as strength, compressibility, and permeability.

In these video clips, you'll see how the classroom activities play out in the hands of an expert. Chris addresses some of the challenges that come up in finding heaviness for size. He finds that using his senses is not a reliable way to estimate weight. He asks how error can creep into volume measurements, and why a reading on the digital scale keeps changing. Knowing how a scientist thinks about these activities will help you listen to your students' ideas about the weights, volumes, and "heaviness for size" of different earth materials.

2. How Does a Scientist Think about the Weight Order Investigation?

Text on Screen

Notice How

Both senses and prior experience influence estimates of weight order of equal volumes of different materials.

Sara: Could you order them [40 cc samples of water, mineral oil, sand, and organic soil] by weight?

Notes

Chris: Yes, you would say this [40 cc of water] would be 40 grams and you could do it by feel – by checking out which would be the heaviest and which would be the lightest.

Sara: What are you thinking about?

Chris: What I'm thinking about is how much does something weigh. I'm doing it completely by feel. I'm feeling this being this much pressure, this much weight on my hand and doing a very similar thing as I march through these guys, seeing which one may weigh more, even though all of them have the same volume, except for the empty container.

Sara: I noticed that once you knew that was mineral oil, you switched the order of those two [water and mineral oil].

Chris: I switched those two, and there was something there about previous knowledge, about knowing that oil is generally lighter [for size] than water. And there is a slight difference in weight between these two.

Sara: Do you want to use the scale to check your order estimate?

Chris: Sure. This [the container] is 26 grams, so I have a weight of the container of 26 grams. Then I go to water and it is 65 – 66 grams. Subtract away the 26 grams for the container, and it's 40 grams. 40 grams of water for 40 cc's of water.

Chris: [Weighing the organic soil] Oh, it's so much lighter! So here, it's 48 grams for this particular material [and the container], which is organic soil, you told me. So, where would it go? [He places it at 22 grams on the weight line] Does it feel that way? A little bit, yes.

Sara: Often people think that all solids are heavier for their size than all liquids.

Chris: Most people think that way, but we need to recognize that this in itself is a soil, and soils consist of three components: air, water, and solids. So where this may be a soil that's black, and therefore probably organic in nature, it also has air and water and if it is dry, just air. So we end up with what we think of as a solid but is really a soil that will weigh less than water all by itself. It will even weigh less than a mineral oil. This is 40 cc of mineral oil. This is 40 cc of soil, part of which is a solid.

Notes

Text on Screen

Summary

- Equal volumes of different materials can have different weights; some materials are "heavy for their size."

- Soils are composed of 3 components: solids, air and water. There's a lot of air in the sample of organic soil, so it weighs less than the same volume of water.

3. How Does a Scientist Think About What a Weight Line Can Show?

Text on Screen

Notice How

The weight line reveals the relative "heaviness for size" of different earth materials.

Sara: What can a good weight line show us about heaviness for size of these four earth materials?

Chris: From a weight line standpoint, because you know the line is an increasing line, you can see, visually see, how these materials weigh differently even though they have the same volume. If I were to take, for instance, this organic [soil] which has a weight of about 20, 19 grams, I could say, "there's where the organics sit." But then I can take the sand, which is closer to 60, and see that it's all the way down here. Now I have the significant difference, with the water falling somewhere in between — hopefully around 40. 33 here [he places the mineral oil on the weight line]. So I can now look at these and say, "Well, visually, I know the organics are less…. the sands are more." And all this is telling me is that, for the SAME volume of material, they weigh different.

Sara: Would you rather look at a measure line, or would you rather look at a data table?

Chris: For me personally, it is a measure line because it is a visualization of results. It's sort of like a graphical presentation that isn't a graph per se. It's just a line but we have everything set up so that one axis is always the same, it's the same volume. Now it's just weight.

Sara: It seems to me that you use that water value – 1 gram per cubic centimeter – as a benchmark that you have in your head at all times for densities. And you can think of other things as a comparison; this is going to be more than 1 gram per cc, this is going to be less than 1 gram per cc. Are there other benchmarks [values] that you have in your head for density?

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Chris: There are other numbers that I use in soils. For instance I know that most soils have a certain density which is, in reality, a relationship to water. I know that a soil particle will have a density that is two and a half to three times that of water. So, if I have a full volume of a particle – a 40 cc particle –

Sara: That would be called a stone?

Chris: It would probably be a rock, yes. It would probably be a good size gravel. If I know that, then I know that it will probably weigh two and a half to three times more than [40 cc's of] water. I use that on a regular basis.

Similarly I know that plastics typically weigh less than [an equal volume of] water. And plastics are pretty solid, most of the time, in most of their uses. But their weight to [the same volume of] water is almost the same. It's about 90% of water weight. If I know that I'm using plastics, it will fall just a little bit below water. It's another number that I can use.

Text on Screen

Summary

- Each material has its own "heaviness for size," i.e., density.
- Unlike weight and volume, a material's density has the same value, no matter how big the sample.
- The density of water is 1 gram per cubic centimeter, or 40 grams for 40 cc's.

4. How Does a Scientist Think About Error in Volume Measurement?

Text on Screen

Watch Chris

Consider three different possible causes of error in volume measurement.

Chris: Now we have water and solid particles occupying the 40 cc's of space. The amount of water that we used is actually 20…..no, 18. We've 22 cc's left of the 40 we started with.

Sara: You thought that you had put in 18 cc's. Actually, now it looks like 17.

Chris: It looks like 17.

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Sara: So the volume changed 1 cc. What could account for those changes?

Chris: There are multiple things. The first one is human error. I can't see very well, so maybe I misread the numbers. How did it get to 17?

Sara: What about all this stuff up here?

Chris: That water that still remains? Yes, if it comes down, it could.

It could be because I'm doing that classic balance with my finger method. I could have tipped it away from myself, therefore it looked like it's really 18. In reality I need to place it on a level surface and come down to eye level for it.

Text on Screen

Summary

To measure volume in a graduated cylinder, place the graduated cylinder on the table and read the lowest point of the meniscus at eye level.

5. How Does a Scientist Think about Uncertainty in the Digital Scale Reading?

Text on Screen

Why might the reading on the scale fluctuate between two values?

Chris: Here comes the fun part. How much does it weigh? With the lid on, now it is a hundred and …..three grams. Let's weigh it again and see if it goes to 104. Oh, it goes to 104. Oh my goodness. Now it says 104 consistently. Now it weighs exactly, we think, 104. Maybe it's 103.6.

Sara: So, if it's around 103.5, it might go either way.

Chris: It can go up to 104, it can go to 103. It will keep going back and forth until it finally settles in on something.

Text on Screen

Summary

The uncertainty in the digital scale reading is one half the smallest division (1 gram) on the scale. A sample could be a half a gram lighter or heavier than the reading, or anywhere in between.

Notes