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Agenda

- Powers of 10, Orders of Magnitude, Estimation
- What is going on in classrooms?
- Possible solutions/Changing our curriculum

Frustrating Fermi Problems…

- Benefits
- So what?
- What would a [social] constructivist say?

What are we (as teachers) really asking?

- Do students really understand what their numerical answer *means*?
- Why do I keep getting homework with answers such as, 6.1790489 m?
- How can we teach our students to estimate answers?

What's going on in the lab?

- What students say: Do the work→ get grade = "Science Success!"
- Students are more concerned about *getting the lab done in the time allotted.*
- Students rush to calculate a percent error
  - Anxious if %Error is not within "acceptable" limits
- Students need a clear "purpose" to the experiment

Hart, C., Mulhall, P., Berry, A., Loughran, J., Gunstone, R. (2000). What is the purpose of this experiment?
Or can students learn something from doing experiments? Journal of Research in Science Teaching, *37*(7), p. 655-675.

Authentic Science?

1. Work towards solution to real-world problem or answer a scientific question?
2. Research topic
3. Use instruments & technology?
4. Use “grade-appropriate” math?
5. Analyze evidence & use evidence to support conclusions?
6. Develop new or refine existing questions?
7. Develop or refine procedures?
8. Provide & receive peer critique & feedback?
9. Collaborate with others?
10. Present results?

The Lab Report

- Typical lab reports include:
  - Calculating % Error
  - List possible sources of error
  - \end Lab Report

- What if we asked students to…
  - Peer review & critique labs
  - Revise experiment based on feedback
  - Described possible sources of error and how to mitigate them

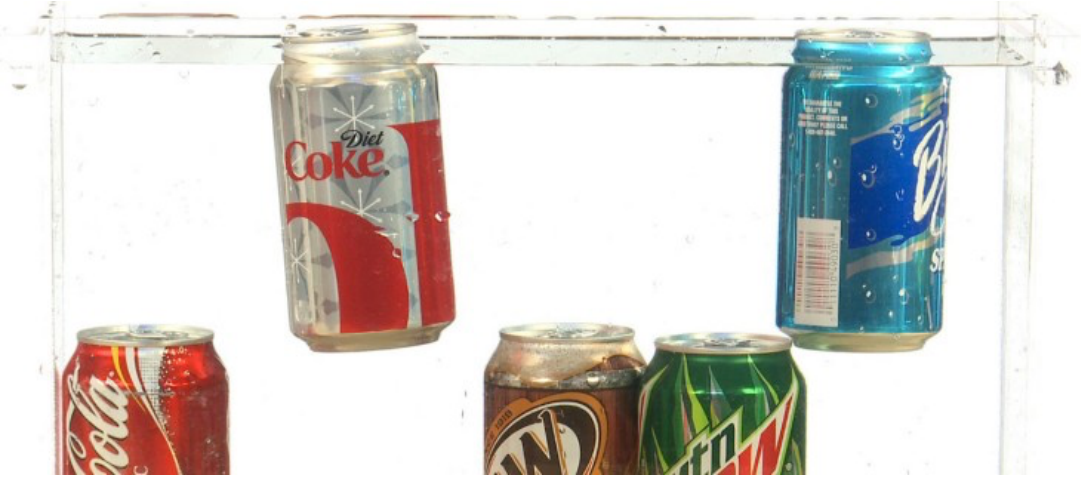
Practical Problems…

- How many piano tuners are in Chicago?
- How many cups of Dunkin' Donuts coffee do I drink a year? How much does that cost?
- If I switch to using a reusable water bottle, how many plastic bottles will I keep out of landfills? What about reusable grocery bags?
- How much money can I save over 1 year by switching 1 IL light bulb with a CFL bulb?
- Are Keurig coffee cups a bargain?
- How many hours do I have to work at $10/hr to save up for a $5500 used car? How many weeks (working at 20hrs/week) will that take? Is this realistic? What other factors go into this answer?
- Cost of college? Repayment of student loans?
- Sports? How many tennis balls does Wimbledon use?

Curriculum Connections

- Density:
  - Coke Floats
  - Density of Al foil

Coke Floats



But what does 40g of sugar look like?

- Amount of sugar in various types of pop:
  - Coke: 40g
  - Mt. Dew: 46g
  - Sprite: 38g
  - Sunkist: 52g

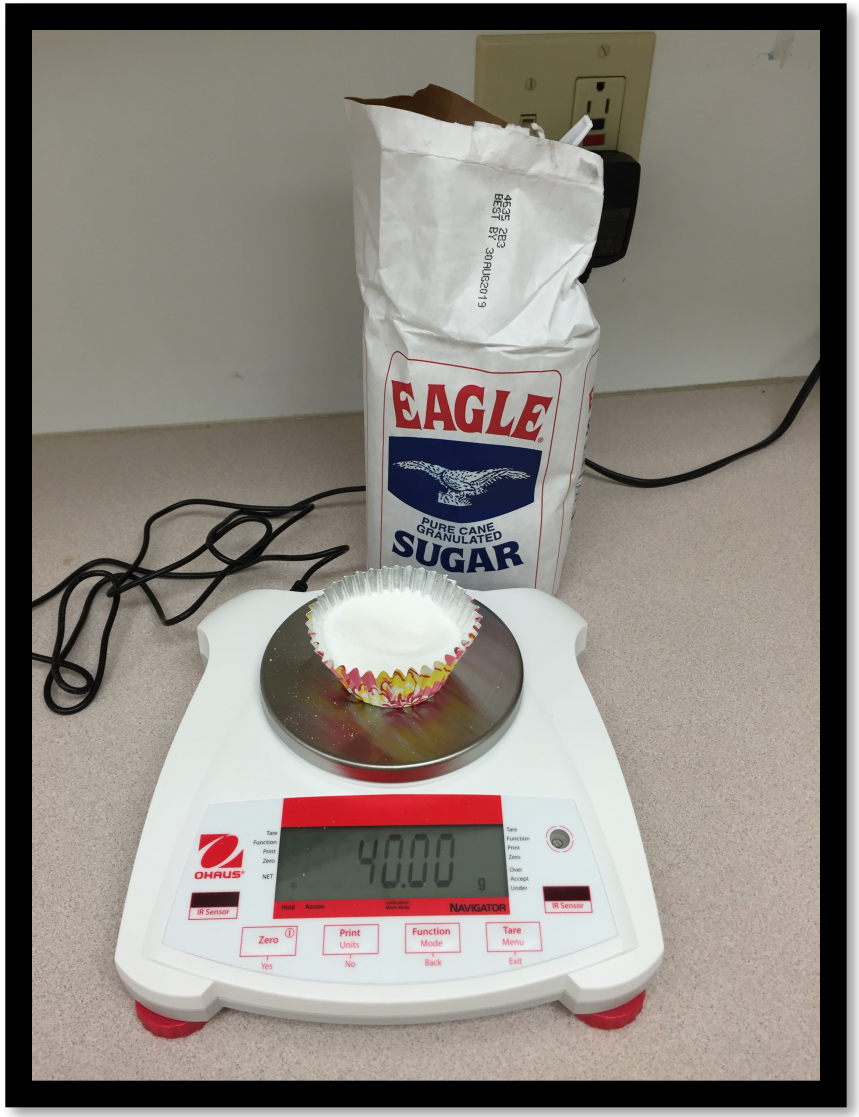
Image source: Steve Spangler

Coke Floats…

- Students pour sugar in paper muffin cups to ***estimate*** what 40 g of sugar looks like.

- ¼ muffin cup?
- ½ muffin cup?
- ¾ muffin cup?
- 1 muffin cup?

- Finally, students mass their muffin cup & sugar, then add/subtract to get 40g.



Thickness of Al foil

- Students have to calculate the thickness of Al foil.
- Materials:
  - Rulers
  - Scissors
  - Markers
  - Scale
  - ρ = 2.7g/cm^3

$$Density = \frac{mass}{Volume} = \frac{mass}{Length\ x\ Width\ x\ Height}$$

Revised procedure

- Students work in cooperative groups to develop method to calculate thickness.
- After a bit of time, have students share ideas with another group for peer feedback & critique.
- Students revise technique, if necessary
- Students share results with class
  - Accurate? Precise?
- Calculate % Error
- *How could they revise their procedure to make it more accurate?*

From the Fine Folks at Reynolds wrap

	Inches	Microns (μm)	Mils
Standard Reynolds Wrap	0.00064	16.256	0.64
Heavy Duty Reynolds Wrap	0.0093	23.622	0.93
Extra Heavy Duty Reynolds Wrap	0.00137	34.798	1.37

FYI: 1 mil = 0.001in

Extensions?

- How many atoms thick?
- Compare to Rutherford's Gold Foil Experiment
  - Is Al foil thicker?

Rethinking Fermi?

- What is the purpose?
- Connections to students' interests and experiences?
- Practical? Relevant? Authentic?
- How can estimation be incorporated in existing labs/activities?
- How can we incorporate opportunities for our students to pose their own "Fermi" questions & make their own OoM estimates?
- Discipline-based Fermi questions
- Provide concrete references & comparisons for our students.