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UNIVERSITY OF LOUISVILLE
CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT

PIMSER
Partnership Institute for Math & Science Education Reform

Classroom Embedded Assessment [CEA] Title: Modeling Weight and Volume

a. Targeted Performance Expectation(s)

5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [*Assessment Boundary: Assessment does not include distinguishing mass and weight.*]

b. Learning Goal(s)

1. Conceptualize and articulate scientific models as "tools for thinking" (*Science & Engineering Practice (SEP) of Modeling*)
2. Conceptualize and represent matter as composed of invisibly tiny particles (CCC-scale and DCI)
3. Use particle model to represent real-world macroscopic phenomena

SEP – Develop and use a model
- Develop a particle-level model of matter.
- Use that model to describe phenomena of weight and volume when mixing substances.

CCC – Scale, proportion and quantity
- Natural objects exist from the extremely small to the immensely large.

DCI – Structure and Properties of Matter
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g. weight).

c. Instructional Context

a. CEA given near the end of a 3-week unit. Students are engaged with a series of demonstrations and asked to consider what the demos have in common and how they might explain what was happening. Demos included: open bottle of strong perfume (smell of perfume mixes with air); drop of food coloring in a clear container of water (food coloring particles slowly mix with water); adding salt to water; freezing water. Focus question for the labs in this part of the unit: What changes and what stays the same when substances are mixed? Ideas students explore are things like: volume and weight of mixed compared to pre-mixed individual substances; visibility when mixed; where do the substances go? Students have generated questions from observations and placed them on the driving question board.

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Scientific modeling is introduced [see Tretter & McFadden, (2018). People as particles: Modeling structure and properties of matter with fifth graders. *Science and Children*, *56*(4), 67-73.]

b. Instructional experiences across the 3 weeks:
   - Engage with series of demos and labs. Students generate questions.
   - Introduce scientific modeling. What it is and isn't. How scientists use models to explain phenomena and make predictions about other related phenomena. Begin to develop criteria for a good scientific model.
   - Conduct investigation to consider the impact on weight and volume when substances are mixed and to begin development of a particle model of matter. Blue Marbles + Red Marbles, White Rice + Wild Rice, Marbles + Rice, Ethanol + Water. Elicit initial model. Students determine in labs that weight is conserved but volume is not necessarily conserved. Generate additional questions to explore.
   - Additional tests of models as needed. (water + marbles, sand + small pebbles, sugar + water, salt + water) Continue to account for volume and weight.
   - Explore closed systems and track properties of materials and weight of system. Teacher demo with: Plastic soda bottle + vinegar + baking soda. Track weight, observations – see, hear, feel – before and after mixing. Use model to explain. Revise model as needed.
   - Stations – Focus question – What changes and what stays the same when matter changes? Series of stations where students mix various combinations (see part (a) above) and measure + document weights and volumes before and after. They then generate a model (drawing) showing what is happening at the particle level.

d. Student Task/Prompt

Students were given the following prompt:

> ***Create a model to help explain your answer to the focus question for the labs: Are weight and volume conserved when you mix materials together? Use your model to answer the question, citing evidence from your labs to support your answer.***

(*They have viewed mixing of macroscopic 'particles' like rice and marbles and can use these observations to help explain the change in volume when ethanol and water are mixed, for example, or salt dissolved in water*.)

e. Success Criteria

At this stage in the instructional sequence, a level 4 response on Merritt, Krajcik, and Shwartz (2008) particle model learning progression – see below – would be on target for 5th grade students. In 6th grade students are asked to add thermal energy considerations, moving up to level 5 on the progression with consideration of motion. By end of middle school they should reach level 6, which includes all states of matter and phenomena such as the water cycle and energy considerations.

Increasing complexity

Level	Category	Particle Model
6	Complete Particle	All relevant substances are made up of particles. Particles are identified as atoms/molecules. The particles are in motion relevant to a particular state, for example, in the gaseous state, there is empty space between the particles and the particles move randomly.
5	Basic Particle	All relevant substances are made up of particles. There is empty space between the particles. The particles are in motion.
4	Incomplete Particle	A substance is made up of particles. There is empty space between the particles.
3	Mixed	Combines both particle and continuous ideas. The substance is made up of particles within a continuous medium.
2	Continuous	No notion of particles,
1	Descriptive	Describes what is happening in words and/or draws an exact replica of phenomena
0	No response	No response or nonsense response.

Figure 3. Learning Progression for the Particle Model of Matter

From: Merritt, Krajcik, J., & Shwartz, Y. Development of a Learning Progression for the Particle Nature of Matter. Paper presented at Proceedings of the 8th international conference on International conference for the learning sciences-Volume 2. 2008.

And can apply a rubric to identify which aspects of thinking students have acquired or still need to work on.

Criteria	2	1	0
Particle Nature	Both substances are represented as separate particles.	One substance is represented as particles. The other is represented as being continuous.	Neither substance is represented as being made of particles.
Mixing	Particles of one substance are shown being mixed evenly with other particles.	One substance is represented as particles but is not shown how it is mixed	Neither substance is represented as particles nor shown how they are mixed.

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		with particles of the other substance.		
Size	Representation notes that the particles are too small to be seen with the naked eye.		Representation does not note that particles are too small to be seen with the naked eye.	
Volume	Representation shows effect of particle size on volume when mixing – slight decrease in volume when mixing substance with larger particles with a substance with smaller particles.		Representation does not account for change in volume.	
Weight	Representation shows that the number of particles does not change when substances are mixed, therefore the weight does not change.		Representation does not account for the change in weight.	

f. Next Instructional Steps

What are the next instructional steps? (general, for all students with exceptions noted below)

- Revisit and refine criteria for what makes a good scientific model.
- Discuss strengths and limitations of model.
- Discuss ways to represent objects too small to be seen with the naked eye.

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- For those who need it, provide additional experiences with different substances to mix that do not react, such as marbles + water, sand + small pebbles, salt + sand, salt + water. For those who got mostly "2" on rubric above, give additional experiences beginning with invisibly small particles (salt & water, sugar & cold water, sugar & hot water – to begin exploring impact of heat)
- Use class consensus model to provide feedback or for self-assessment of individual models.
- Use model to predict outcome of mixing, then test using substances.
- Note individuals with no particle nature or partial particle nature represented; continue to monitor and question as unit progresses. What would be observed if matter was continuous and not particulate? What do their models show? What observations have they made that support their model?

g. Student Work Samples

None

h. Reflection and Revision

None

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