Some Comments on the Current State of Science Assessment in the US

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PADI Science Assessment Forum

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The State of State Standards-Based Science Assessments

- A Report of the Committee on State Standards in Education by the National Research Council says: "[State education leaders] generally take standards-based reform and accountability for granted, viewing its approach as a 'central framework guiding state education policy and practice.'" From *Common Standards for K-12 Education?* (NRC, 2008)
- Standards-based science assessment is now the law of the land and not likely to change in the near future.

NCLB Mandated Statewide Testing: Reports and Remedies as Seen by the Public

- Minneapolis Star Tribune – Only about four out of 10 Minnesota students can be labeled “proficient” in science according to results released today by the Minnesota Department of Education. Of the three grade levels given the new tests, about 39 percent of fifth-graders, 38 percent of eighth-graders and 43 percent of high school students did well enough on the Science MCA-II.
- The state has several initiatives to improve education in the Science, Technology, Engineering and Math (STEM) fields, including the Math and Science Teacher Academy, which began this year and focuses on improving teacher skills.

- Providence Journal - The results of the first statewide tests in science show most Rhode Island students do not grasp the key scientific concepts educators expect from them, with just 24 percent scoring proficient on the tests statewide – a far lower pass rate than similar tests in reading, writing, and math.
- Plans for addressing the problem include introducing Physics First, training H.S. teachers to use computer simulations, and teaching elementary teachers to use hands-on science.

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- Concord Monitor – Many New Hampshire students aren't meeting state standards in science, according to the first round of statewide testing in the subject... Fourth-graders performed the best, with 51 percent considered proficient or better. Only 22 percent of high school students achieved a score of proficient or better. Middle school students were proficient 26 percent of the time.
- School principals in and around Concord said the scores will be useful for developing better science classes and identifying students who might be struggling.

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- Can the results of statewide testing really be used to improve teaching and learning in science?
- What would it take for the results of testing to provide evidence of student learning needed to make improvements in teaching?

Standards → Assessment → Improvements in Teaching and Learning

California 8th Grade Content Standard:

Students know when the forces on an object are balanced, the motion of the object does not change. [Newton's 1st Law]

Aligned Test Item:

A ball is dropped from the top of a tall building. As the ball falls, the upward force of air resistance becomes equal to the downward pull of gravity. When these two forces become equal in magnitude, the ball will:

A. flatten due to the forces
B. fall at a constant speed
C. continue speed up
D. slow to a stop

- If students did poorly on this item and others like it, instruction could be aimed at this learning goal.

Massachusetts 8th Grade Content Standard:

Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land, and atmosphere.

Aligned Test Item:

Harmful ultraviolet rays from the Sun are primarily absorbed by

A. dust
B. ozone
C. land masses
D. water vapor

California 8th Grade Content Standard (supporting idea):

Students know the idea of atoms explains the conservation of matter: In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.

Aligned Test Item:

The following equations represent chemical reactions.

1. $2Na + 2H_2O \rightarrow NaOH + H_2$
2. $H_2 + O_2 \rightarrow H_2O$
3. $Mg + CL_2 \rightarrow MgCl_2$
4. $NaOH + MgCl_2 \rightarrow NaCl + MgOH$

Which equation shows that the total mass during a chemical reaction stays the same?

What is needed for the results of state testing to be used to improve teaching and learning?

- We need clearly stated learning goals, most of which are going to require additional elaboration to specify more precisely what is expected of students (e.g., boundaries and exclusions, as in NAEP 2009).
- We need much larger sets of items written with the intention of finding out what students know about a particular idea, not just items that are topically aligned and placed in the content-standard bin having the closest fit. (Item/matrix sampling?)
- Multiple choice items should include misconceptions as distractors to find out the ideas that students actually do have.
- The learning goals should be clustered around conceptual themes (fundamental theoretical structures) so that assessment can be used to identify gaps in knowledge that limit understanding of the larger concept.

What would be learned from analyzing assessment results if these conditions were met?

Substance-level understanding of conservation of matter

Key Idea: Whenever substances interact with one another, regardless of how they combine or break apart, the total mass remains the same.

1) We write a more complete statement of what students are expected to know. (Clarification Statement)

Students should know that when substances mix, undergo chemical reactions, change state, or dissolve, or when objects are cut or broken into smaller pieces, the total mass of all the matter will always remain the same. They should also know that regardless of the form that the products of these processes may take (for example, when a sugar cube dissolves in water or a chemical reaction produces a gas), the mass will always stay the same. Students should know that if it appears that the mass has changed, it is because some material has not been accounted for. Students are not expected to know that mass is not conserved in nuclear reactions or other subatomic interactions.

(This is a rule to be applied in a variety of substance-level contexts. Items should cover a variety of those contexts and common misconceptions.)

Items testing substance-level understanding of conservation of matter (national sample ~ 2000 students)

Item Context	Percent Correct	Rasch Item Difficulty (Logit)
Stick of butter cut into pieces	70%	-1.39
Sugar dissolving in water in a sealed container	37%	.14
Plant dying in a sealed container	36%	.23
Liquid expanding in a heated thermometer	29%	.58
Chemical reaction in a sealed container (gas formed as product)	27%	.67
Mold growing on bread in a sealed container	17%	1.29

A related idea. Part of a cluster of related ideas: Conservation of Matter at the Atom Level

Key Idea: Whenever atoms interact with each other, regardless of how they are arranged or rearranged, the number of each kind of *atom* stays the same and, therefore, the total mass stays the same.

(Now students have an explanatory model for conservation of matter)

Clarification statement

Students should know that atoms are not created or destroyed when substances mix, undergo chemical reactions, change state, or dissolve, or when objects are cut or broken into smaller pieces. They should know that the total number of each kind of atom always remains the same regardless of what happens to the matter (mixing, chemical reactions, changes of state, dissolving, or objects being cut or broken into smaller pieces), and that the mass of an atom does not change. They are expected to know that if the measured mass has changed, it is because some atoms have not been accounted for.

Testing for correct and also for alternative ideas

Context: One liquid is poured into another in an open jar and a gas forms. The resulting weight of the liquids is less: Why?

A. Some atoms went into the air	39%
B. Some atoms were destroyed (documented misconception)	27%
C. Some atoms became heavier	15%
D. Some atoms become lighter	19%

What else can we learn?

- We can gain insights into student thinking (cognitive research)
- Knowledge + reasoning
- TRUE vs. NOT TRUE; design vs. evaluate a controlled experiment or confounded study; predict vs. explain a phenomenon; less vs. more; etc.

Idea A: Motion energy (kinetic energy) is associated with the speed and the mass of an object. (from 4E/M4b*)

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Responses vary with the kind of reasoning expected.

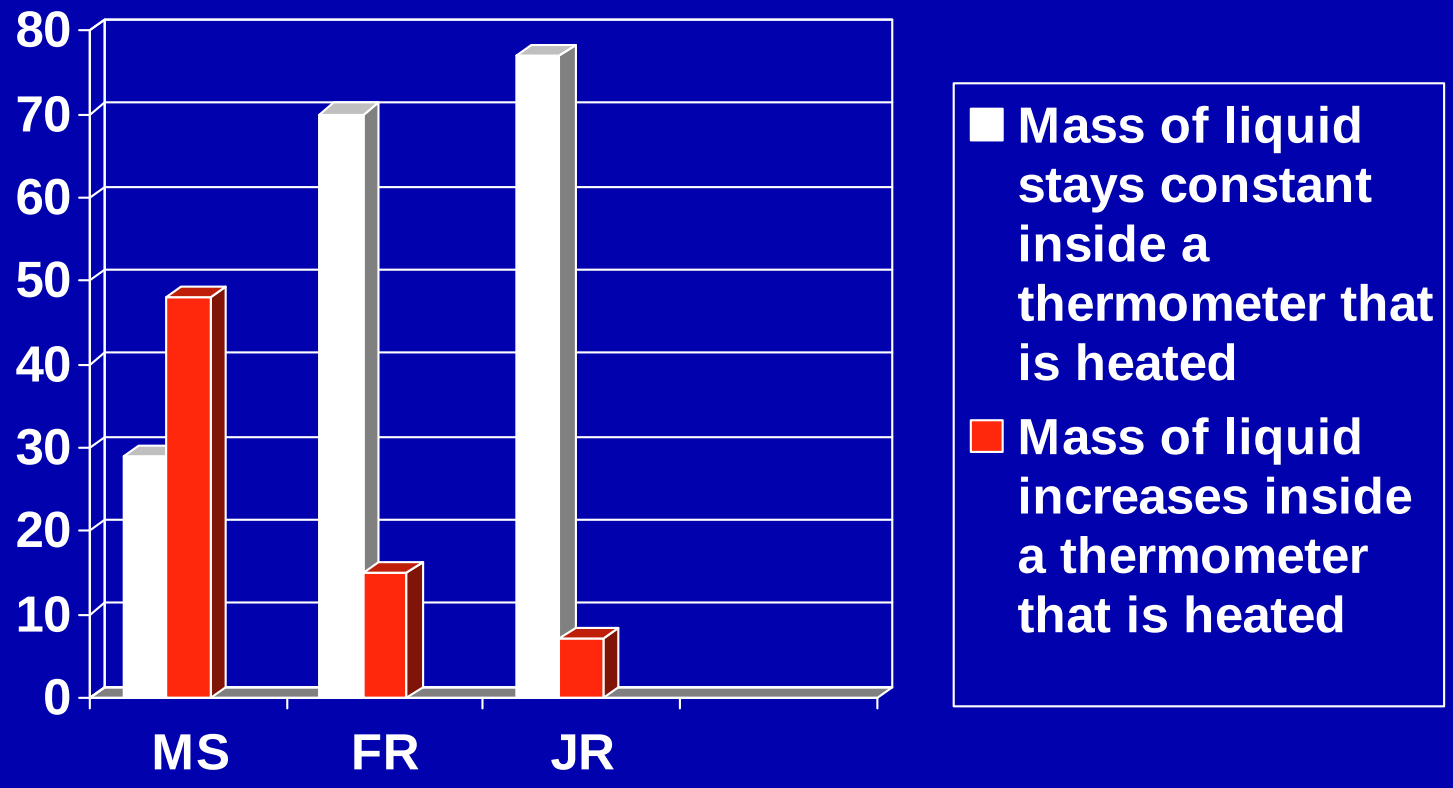
Correct Answer to Item (N~100)	% Correct	Rasch Item Difficulty (Logit)
The motion energy (kinetic energy) of an object depends on the speed and the mass of the object.	62%	-1.0
For two objects traveling at the same speed, the object with more motion energy weighs more.	26%	.72

What else can we learn?

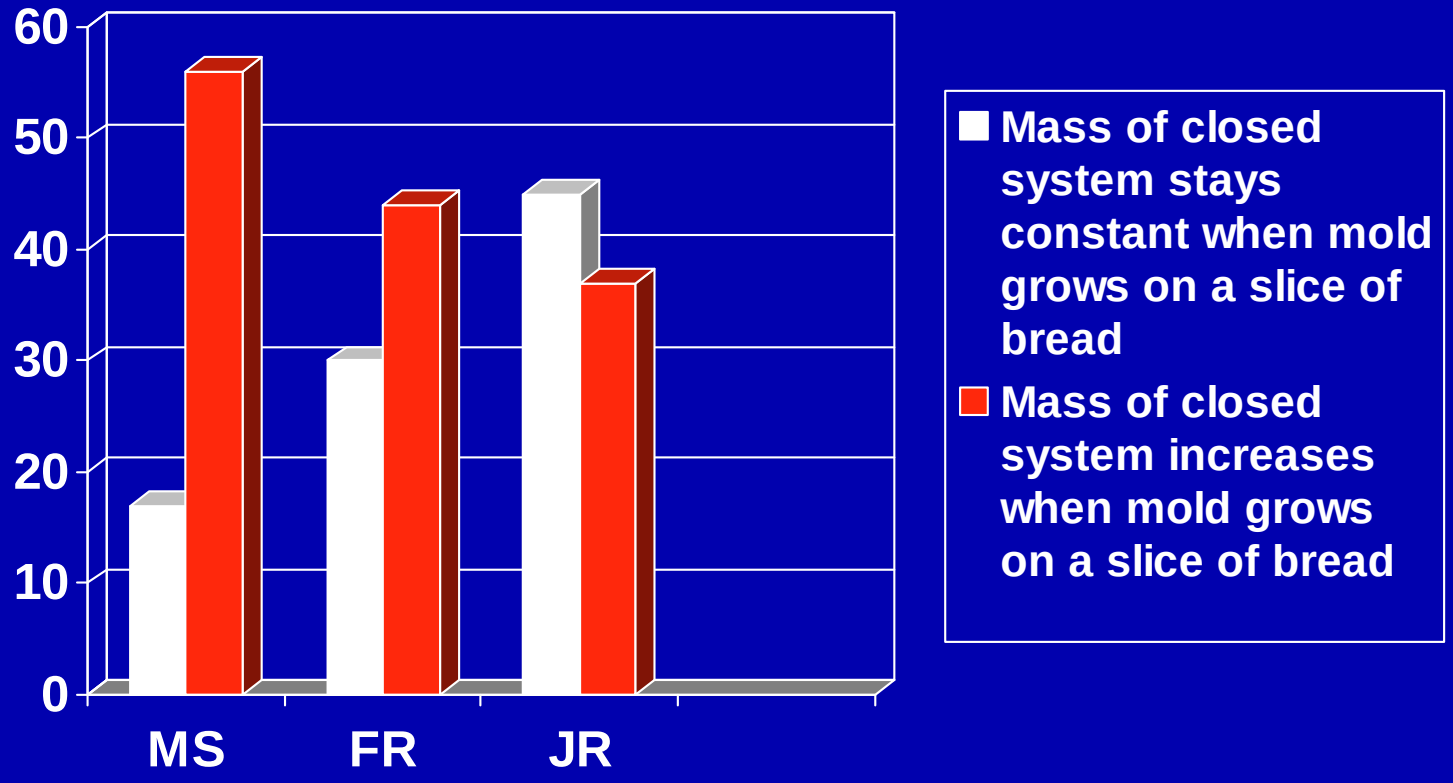
Lots of things, but one in particular that is very interesting…

We can pinpoint change over time for very specific ideas, subideas, misconceptions, and cognitive abilities.

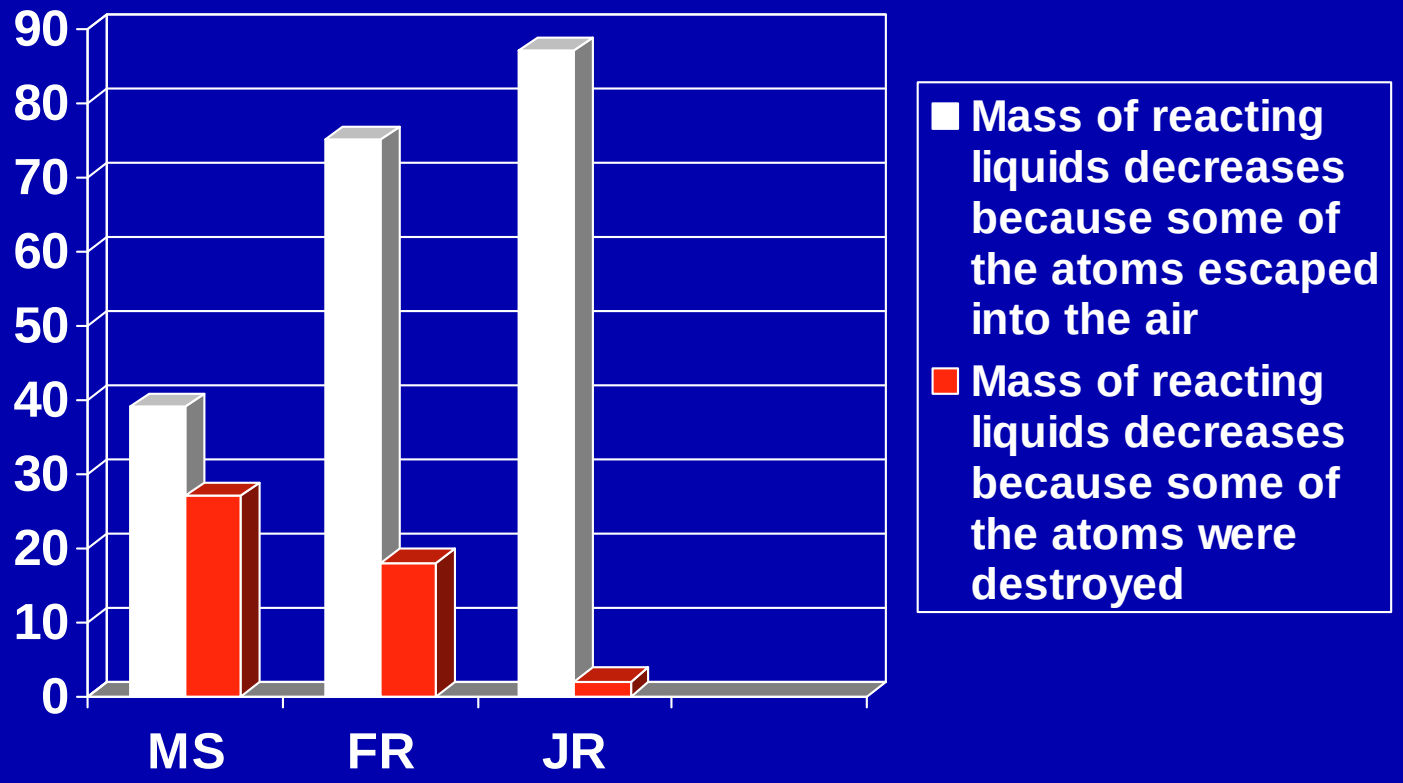
Conservation of Matter: Substance Level (Thermometer)



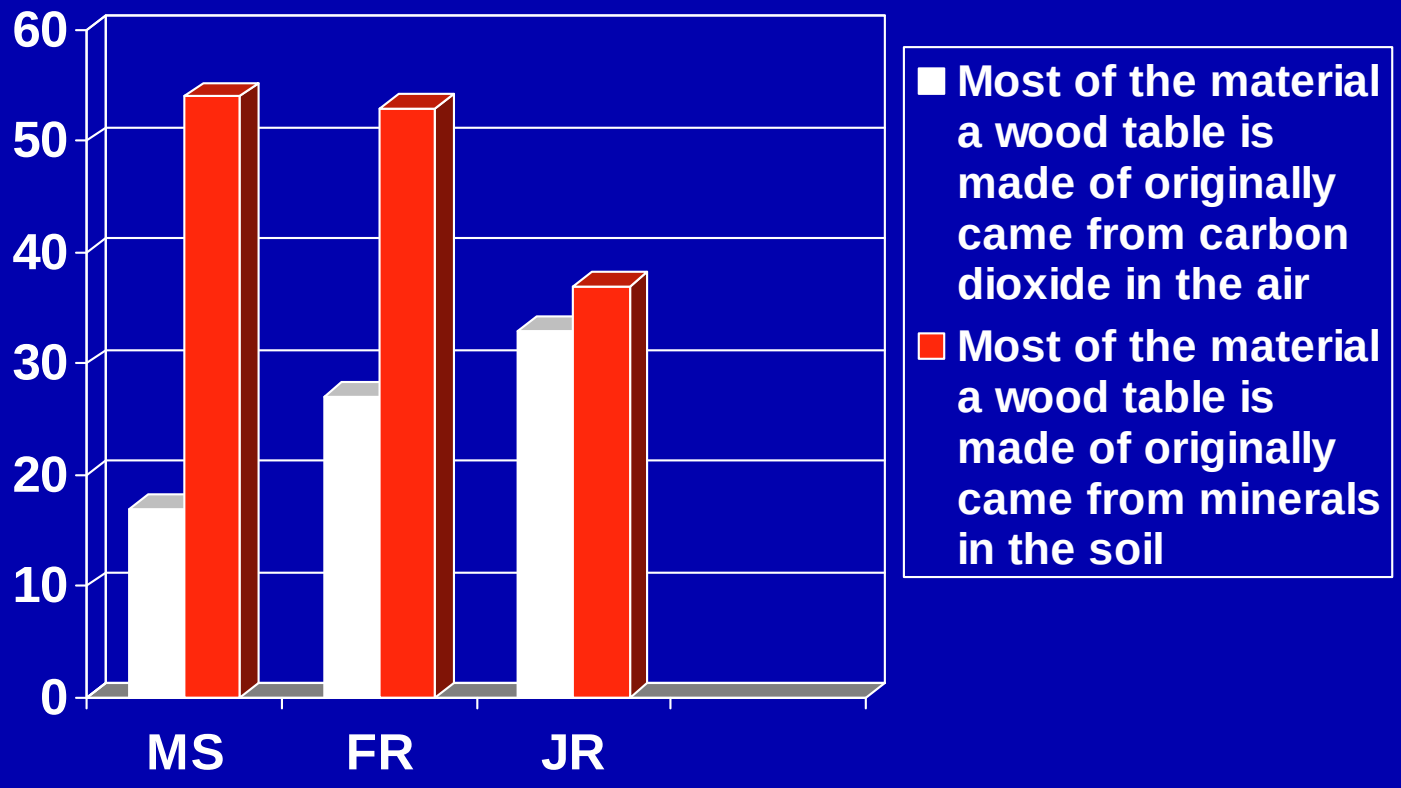
Conservation of Matter: Substance Level (Moldy Bread)



Conservation of Matter: Atomic Level (Atoms destroyed)



Wood Comes from Carbon Dioxide in the Air (Remember the Private Universe videos?)



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