Determining the Appropriateness of Terminology in Content-Aligned Assessments for Middle School Students: Examples from Plate Tectonics

National Association for Research in Science Teaching Annual Conference
New Orleans, LA April 15-18, 2007

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The work that is described here is part of a larger project to develop student assessment items in science and mathematics that are precisely aligned with content standards. This paper describes how we use pilot testing to gain insight into student thinking about ideas we are testing in middle school about plate tectonics. These insights are used to improve test items as well as statements we write that clarify our expectations for students.

During pilot testing students responded to assessment items that are aligned to specific ideas in *Benchmarks for Science Literacy (*AAAS, 1993) and the *National Science Education Standards* (NRC, 1996). Here we focus on how pilot test data can be used to determine the appropriateness of certain terminology in clarification statements and related assessment items. This work is funded by the National Science Foundation Grant # ESI 0352473.

PILOT TEST METHODS

The pilot testing included students in grades 7 – 8 from three school districts across the country: (1) A middle school and a high school in a northeastern suburb having a student population that is 40% White, 48% African American, and 8% Hispanic, with 25% of the students eligible for free and reduced lunch; (2) a middle school in a northeastern suburb having a student body that is 95% White, where 10% of the students are eligible for free and reduced lunch; (3) a middle school in a small southern town with a student body that is 70% White and 24% African American, where 33% of the students are identified as economically disadvantaged. Interviews of ten 9th grade students were conducted in a new high school with unreported population demographics in the western United States, in which 44% of the students are eligible for free and reduced lunch.

During pilot-testing, students responded in writing to the following questions for each assessment item. (For questions 3-6, students are asked to explain why an answer choice is correct or not correct or why they are "not sure.")

1. Is there anything about this test question that was confusing? Explain.
2. Circle any words on the test question you don't understand or aren't familiar with.
3. Is answer choice A correct? Yes No Not Sure
4. Is answer choice B correct? Yes No Not Sure
5. Is answer choice C correct? Yes No Not Sure
6. Is answer choice D correct? Yes No Not Sure
7. Did you guess when you answered the test question? Yes No
8. Please suggest additional answer choices that could be used.
9. Was the picture or graph helpful? If there was no picture or graph, would you like to see one?

10. Have you studied this topic in school? Yes No Not Sure
11. Have you learned about it somewhere else? (TV, museum visit, etc)? Where? Yes No Not Sure

From their written responses, we are able to determine: (1) whether students used the targeted content standard to answer the question or if they used other knowledge instead, (2) whether the item was comprehensible to them, and (3) whether the answer choices were plausible to them. Mismatches between the answer choices that students select and the reasons they give provide us with information about whether the item is likely to yield false positive and false negative responses. Student comments also provide information regarding better wording for clarification statements and on misconceptions students may hold. In this paper we focus on examples of pilot test results that help us determine the appropriateness of certain terminology in clarification statements and in assessment items aligned to the ideas in those clarification statements.

Four Examples of How Students Respond to Terminology in Test Questions

Example 1- Earth's plates are made of *bedrock*.

Although *Benchmarks for Science Literacy* uses the term "bedrock" at grades 3-5, concern about how familiar this term is to students and how useful it is in test item development prompted us to write two items that are identical except that one uses the term "bedrock" and the other uses the descriptive phrase "solid rock." These items were piloted at two different middle schools in two eastern states at grades 7 and 8. The students had had typical instruction related to this content, i.e., instruction that was not necessarily targeted to the meaning of the word bedrock. In the pilot test, half of the students in each class were randomly given the "bedrock" version of the test item and half were given the "solid rock" version.

Version 1 with "solid rock"

Which of the following are part of earth's plates?
A. Solid rock of continents but not solid rock of ocean floors.
B. Solid rock of ocean floors but not solid rock of continents.
C. Solid rock of both the ocean floors and the continents.
D. Solid rock of neither the ocean floors nor the continents.

Is Answer Choice Correct?	A	B	**C**	D	% Correct (n=51)
Yes	11	5	26	1	51.0%
No	28	34	14	39	
Not Sure	12	12	10	11	
No Response	0	0	0	0	
Multiple selections for single answer choice	0	0	1	0	

Version #2 with "bedrock"

Which of the following are part of earth's plates?
A. Bedrock of continents but not bedrock ocean floors.
B. Bedrock of ocean floors but not bedrock of continents.
C. **Bedrock of the ocean floors and the continents.**
D. Bedrock of neither ocean floors nor continents.

Is Answer Choice Correct?	A	B	**C**	D	% Correct (n=64)
Yes	5	7	29	5	43.8%
No	32	30	11	32	
Not Sure	27	27	23	27	
No Response	0	0	0	0	
Multiple selections for single answer choice	0	0	1	0	

Students who answered the "bedrock" question were asked a follow-up question that asked them what bedrock is:

- Thirty-five of 57 (61%) of the students who answered the follow-up question responded that they did not know what bedrock is.
- Students who attempted to define the term said:
    1. The bed of rocks on the ocean floor
    2. The bottom layer of a rock
    3. Like the ocean floor
    4. The bare rock under dirt and sand
    5. The deep rock of the crust
    6. Bedrock is rock that is in the ground
    7. A type of layering of loose pebbles that have been fused together
    8. Rocks and sediments that are on the bottom of the continent or ocean
    9. Rocks on the bottom of the ocean
    10. Rock Maybe
    11. It is the rock that is on the bottom of an ocean plate

Analysis:
There are a greater number of "unsure" responses when "bedrock" is used. The item using "bedrock" had approximately 41% "unsure" responses to the answer choices (23-27 out of 64), and the item using "solid rock" had approximately 22% "unsure" responses (10-12 out of 51). Fifty-one out of 57 students (90%) who wrote comments about the original bedrock item indicated that they did not know what bedrock is and 35 out of 57 students who answered the follow-up question about bedrock said they did not know what bedrock is. Additional students had incorrect ideas of what bedrock is. Despite this lack of understanding of the term, 44% of the students were able to correctly answer the bedrock item, compared to 51% of students answering the "solid rock" item. Students apparently translated "bedrock" to the intended meaning of "solid rock" without knowing for sure what the word bedrock means.

In spite of their relative success, we decided not to include the term "bedrock" for assessment purposes because it is not needed to test students' understanding of what plates are made of and because it has the potential to confuse students, as evidenced by the large percentage of students who said they were unsure of their answers.

Example 2 – There is no gap between the plates.
Previous work (Marques, L. and Thompson, D., 1997; Unpublished Horizon Research, Inc. pilot data, 2005; Unpublished AAAS/Project 2061 teacher interview data, 2005 and 2006) and written explanations and drawings students provided during pilot testing showed that students often hold the idea that plates are not in contact with each other or are not always in contact with each other. Some students think the oceans are between the plates and some think a sea of magma is between the plates.

The clarification statement for the key idea about plates originally said there was no "gap" between the plates:

> *Students are expected to know that the rigid, outer layer of the earth is made of separate sections that are called plates and that the plates fit closely together so that the edge of one plate directly touches an adjacent plate with no gaps between them.*

The following assessment item was written to test student knowledge of this idea.

Which of the following is TRUE about earth's plates?
A. Earth's plates are separated by oceans.
B. Earth's plates lie alongside one another with no gaps between them.
C. Earth's plates are separated by large pools of melted rock.
D. A single plate covers all of the earth's surface.

Is Answer Choice Correct?	A	B	C	D	% Correct (n=42)
Yes	12	12	7	1	29.0%
No	23	21	22	38	
Not Sure	6	8	13	3	
No Response	1	1	0	0	
Multiple selections for single answer choice	0	0	0	0	

The students' written responses for answer choice B revealed a variety of ways that they understood "gap." Of the 36 students who wrote explanations for why the answer choice was correct:

- 8% said there are gaps because there are oceans between the plates.
- 11% said that gaps have to occur where plates separate.
- 6% said "no gap" means the plates would have to be connected into one large plate.

The results suggest that a number of students thought that gaps are discontinuities between plates that give plates identity and allow magma to rise between the plates when they separate. These

students could have rejected the correct answer and selected one of the incorrect answers even though they understood the idea that plates are in close contact with each other.

A similar result was found when we interviewed 9th grade students. Thirty percent of these students said that there must be "gaps" because otherwise the magma could not rise where plates separate. Both data sets show a significant number of students appear to correctly understand "gap" as the discontinuous fracture that allows plates to touch and also allows magma to rise at the plate boundaries. When designing the items and the clarification statement, "gap" was intended to mean a large open space extending down through the entire vertical thickness of the plates. A significant number of students interpreted it differently. Based on these results, we have removed the word from the clarification statement and the item.

Revision of the clarification statement:

Original: Students are expected to know that the rigid, outer layer of the earth is made of separate sections that are called plates and that the plates fit closely together so that the edge of one plate directly touches an adjacent plate *with no gaps between them*.

Revised: Students are expected to know that the rigid, outer layer of the earth is made of separate sections that are called plates and that the plates fit closely together *so that each plate directly touches all the plates next to it*.

Answer choice B was revised to:

B: Earth's plates fit together so that they always touch each other.

Example 3: Use of the descriptive phrase "plates press together" instead of the technical term "converge."

Although instruction typically uses technical terms such as convergent, divergent, and transform to describe types of interactions at plate boundaries, these terms are often confused by middle school students. Even in everyday usage, the meaning of these words is not understood by many middle school students. Therefore, we have not held students accountable for these terms in assessment, and instead we use descriptive phrases that are scientifically accurate and promote mental models of processes. We use the phrases "press together," "pull apart," and "scrape alongside each other" to describe the interaction between plates at plate boundaries.

Using the item below, we probed student understandings of "plates press together."

What happens as two plates press together over many millions of years?
A. The solid rock at the edges of the plates is pushed upward and forms mountains.
B. The solid rock at the edges of plates grinds into small rocks and is eroded away.
C. The plate material stops moving and nothing else happens.
D. The plate material moves so slowly that nothing noticeable happens.

Of the 42 students who responded to this item, only one indicated being confused by the phrase "plates press together." In a follow-up question, students were explicitly asked: "What does it mean when we say that plates press together"? Their responses fall into 5 categories:

1)	Plates converge, or converge and subduct.	7/42 students	(17%)
2)	Plates collide, crash, or run into each other.	9/42 students	(21%)
3)	Plates collide, but slowly.	2/42 students	(5%)
4)	Plates push, come, move, or are forced together.	23/42 students	(55%)
5)	Don't know.	1/42 students	(2%)

The use of the phrase "press together" is intended to promote a mental model of a slow process and to avoid encouraging the misconception of plates crashing into each other at a fast pace. It also draws on students' understanding of pushes and pulls as forces. In response to the follow-up question, most students explained "plates press together" with words that suggest they were thinking of a slow process, but 21% of them wrote descriptions that could mean suggest fast collisions. Further work is needed to determine exactly what the phrases "press together" and "collide" mean to students.

Example 4: Considering plate motion as the movement of "plate material."

It is common to refer to the "movement of plates" in curriculum materials and instruction. A key idea we are using for assessment is "*The plates move very slowly, pressing against one another in some places and pulling apart in other places—sometimes scraping alongside each other as they do."*

Part of the clarification statement for this idea was written to promote student thinking about the process of plate material moving: "Students should know that plate material moves as it is continuously added at one end of a plate and sinks into the earth's interior or crumples up to form mountains at the other end of the plate."

The intent of the clarification statement is to focus instruction and assessment on the process by which plate material is added to one end of a plate and is either subducted or pushed upward to form mountains at the other end. In phrasing the expectations in this way we hoped to discourage the development of a mental model of plates as unchanging entities that circumnavigate the earth. But we also recognized that this might be unfamiliar language to students and we wanted to find out how they interpreted the phrase "plate material." Two items were developed using the term "plate material" rather than "plates" when describing plate motion. An additional follow-up question specifically probed student ideas about what is meant by "plate material."

Item #1

Which of the following describes the movement of earth's plate material?

A. Plate material does not move.
B. Plate material moves but so slowly that the motion can't be measured.
C. Plate material moves about an inch or two per year.
D. Plate material moves about a foot or two per year.

Is Answer Choice Correct?	A	B	C	D	% Correct (n=58)
Yes	2	17	19	6	32.8%
No	41	22	16	32	
Not Sure	15	19	23	20	
No Response	0	0	0	0	
Multiple selections for single answer choice	0	0	0	0	

Item #2
Which of the following is a TRUE statement about the movement of continents and plate material?

A. Continents move but plate material does not move.
B. Plate material moves but continents do not move.
C. Continents move as part of plate material that is moving.
D. Plate material and continents have moved in the past but have now stopped moving.

Is Answer Choice Correct?	A	B	C	D	% Correct (n=41)
Yes	0	3	30	3	70.7%
No	36	32	5	32	
Not Sure	5	5	6	5	
No Response	0	1	0	1	
Multiple selections for single answer choice	0	0	0	0	

Students who answered were also asked two additional questions asking them what is meant by "plate material." One question asked students to list things that are "plate material." Twenty-one percent of the students said that they did not know what plate material is, but 31% of students responded with answers that are correct or nearly correct. In most cases it appears that students translated "plate material" to mean "plate." When asked to provide examples, a number of students answered in terms of plate composition, i.e., the material that they thought plates might be made of.

Students defined plate material as:

Rock floating on the mantle
Plate material is hard once melted rock
Plate material is just a plate moving below the contanent [sic]
The section of Earth's crust

Things students listed as examples of plate material:

Rock, Dirt
Volcanoes, continents, Mts, They lie on plates.

Dirt rock mud they can be packed + hardened
Coal, oil, and natural gas
Hardened magma
Grass water dirt
Soil, metal, rock, because you need something strong to move it.
Clay- because it is durable and its hard, dirt- soft and its in everything underground, coal- hard and it melts easy in plates.

Analysis:
Student uncertainty was different between these two items. Item #2 had a very low number of "unsure" selections (5-6 out of 41), indicating students were fairly comfortable with this item and the use of "plate material." Item #2 had a much higher number of "unsure" selections (15-23 out of 58). Analysis of students who said they were unsure about whether answer choices were correct or incorrect shows that half did so because they didn't know what "plate material" meant and half did so because they did not know the correct rate. The small number of unsure responses on item #2 is also likely due to their knowledge that plate motion is linked to continental drift.

Although many students are not as familiar with the phrase "plate material" as they are with the term "plate," we are continuing to use it in clarification statements and items. The phrase is intended to promote a mental model of a process in which plate material is added at one end of a plate and pushed up or subducted at the other end, and it is intended to discourage the development of the incorrect idea that plates are unchanging entities that move around the earth.

CONCLUSIONS

Two significant conclusions come from this work. First, in assessing student understanding of science ideas, the words that are chosen matter. Therefore, it is critical that assessment be based on carefully thought-out and tested wording of those ideas. Technical terms (e.g., "bedrock") may be unnecessary for testing student understanding, and even wording that is generally thought to be grade level appropriate and in common usage (e.g., "gap") can be problematic. In both cases, the words that were chosen had the potential to hide student understanding of the underlying ideas. To determine which terminology is appropriate, it is important to look carefully at how students interpret those words.

Second, asking students to explain in writing why they selected each of their answer choices is an effective way of determining what students think. The large data sets that can be readily obtained with this methodology provide information from students across diverse geographical areas and student populations. Although student interviews are also useful for confirming findings from pilot testing and for probing more deeply into student thinking, the time, expense, and access they require are limiting factors in their use. This form of pilot testing provides a way of obtaining input from a large number of students that can be used in the design of effective assessment items.

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