ATLAST Plate Tectonics Teacher Assessment
User Manual

1. Overview

The ATLAST Plate Tectonics Teacher Assessment is a 30-item multiple-choice assessment for middle grades science teachers. The assessment measures understanding of the following concepts:

> The outer portion of Earth—including both the continents and the seafloor beneath the oceans—consists of huge plates of solid rock. The plates move very slowly (a few centimeters per year). Plate movement causes abutting plates to interact with one another. Interactions between plates result in events and features that are observable on Earth's surface (e.g., earthquakes, volcanoes and mountain ranges); these typically occur along boundaries between plates. (American Association for the Advancement of Science/Project 2061, 1993).

This user manual describes the background, development, measurement properties, and appropriate uses of the assessment. User manuals for other ATLAST assessments may be found at www.horizon-research.com/atlast.

2. Background

Horizon Research, Inc. (HRI) developed the ATLAST Plate Tectonics Teacher Assessment as part of a larger study. The project—Assessing Teacher Learning About Science Teaching (ATLAST)—was funded by the National Science Foundation under Grant no. DUE-0335328[1]. The goal of ATLAST was to develop instruments that researchers could use to study the theory of action that underlies much professional development for science teachers. Briefly, the model asserts that changes in teacher knowledge lead to changes in classroom practice (mediated by instructional materials), and ultimately, changes in student learning. (See Figure 1.) Despite the prominent role this model plays in professional development design, it has not been studied systematically, in part because of lack of instruments. Among other products, ATLAST developed pairs of assessments—one for teachers and one for students—focused on the same science content. These pairs of assessments enable the study of relationships between teacher knowledge and student learning in specific science contexts. ATLAST assessments exist for three content areas: flow of matter and energy in living systems (photosynthesis and cellular respiration), force and motion (Newton's first and second laws), and plate tectonics.

[1] Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

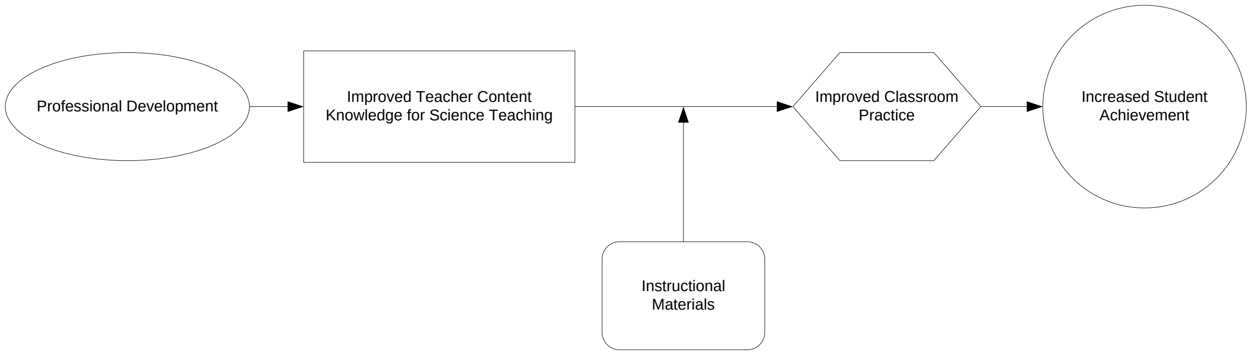


Figure 1
Professional Development Theory of Action

To enable large-scale research, HRI set out to create assessments that would be minimally burdensome, both for the test taker and the researcher. Accordingly, HRI opted for a multiple-choice format, recognizing the limitations of such items. For instance, well constructed open-ended items may probe more depth of understanding than multiple-choice items, but they are more burdensome for both the researcher (in terms of scoring costs) and the test taker (in terms of time required to complete the assessment). In addition, scoring open-ended items requires the training of raters to establish inter-rater reliability.

3. Development of the Plate Tectonics Teacher Assessment

As described above, this development effort was part of a much larger and well-funded project, which afforded a thorough development process. This process is depicted in Figure 2.

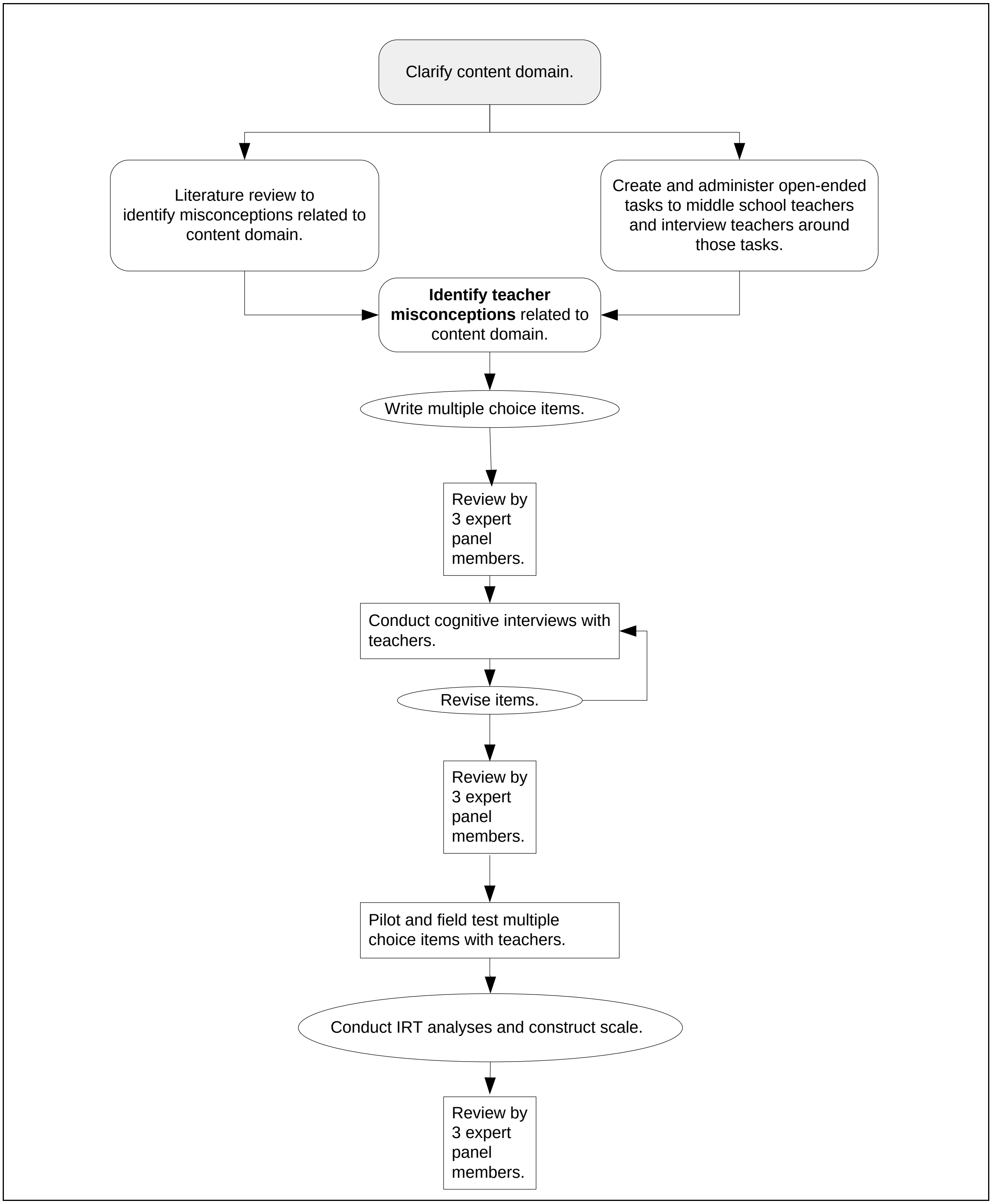


Figure 2
ATLAST Assessment Development Process

3.1. Clarifying the Content Domain

Development began with identifying the target content for the assessment, the ideas that:

> The outer portion of Earth—including both the continents and the seafloor beneath the oceans—consists of huge plates of solid rock. The plates move very slowly (a few centimeters per year). Plate movement causes abutting plates to interact with one another. Interactions between plates result in events and features that are observable on Earth's surface (e.g., earthquakes, volcanoes and mountain ranges); these typically occur along boundaries between plates. (American Association for the Advancement of Science/Project 2061, 1993).

HRI specified the domain by "unpacking" these targeted ideas into 10 "sub-ideas," that were reviewed by three geologists/geology educators, resulting in minor edits. The final description of the content domain is shown in Table 1.

Table 1
Plate Tectonics Content Domain

Targeted Ideas: The outer portion of Earth—including both the continents and the seafloor beneath the oceans—consists of huge plates of solid rock. The plates move very slowly (a few centimeters per year). Plate movement causes abutting plates to interact with one another. Interactions between plates result in events and features that are observable on Earth's surface (e.g., earthquakes, volcanoes and mountain ranges); these typically occur along boundaries between plates. (American Association for the Advancement of Science/Project 2061, 1993).

Sub-ideas

A. The solid outer portion of Earth consists of separate plates of almost entirely solid rock.
  - A1 Plates abut other plates on all sides. There are no visible gaps between plates that are adjacent to each other.
  - A2 The upper portions of some of Earth's plates are the continents and some seafloor beneath the oceans.
  - A3 The rest of Earth's plates do not include continental material but only seafloor beneath the oceans.
  - A4 There are 10 - 12 major plates. Major plates are larger than some continents; plates can be thousands of kilometers across. Plates average 100 km thick, which is 1/60 of Earth's radius.
  - A5 Plates are on top of solid, slightly softened rock. They do not float or move on molten rock or water.

B. Earth's plates (the lithosphere or lithospheric plate) are cold (relative to deeper portions of Earth), strong and brittle and average about 100 kilometers in thickness. Beneath the lithosphere is an almost entirely solid (~99%) layer of Earth (the asthenosphere) which is hot, weak and plastic and extends from the base of the lithosphere to a depth of about 350 kilometers.

C. The plates that make up Earth's surface are constantly moving and changing.
  - C1 All of Earth's plates move very slowly (a few centimeters per year).
    - C1.1 Since the continents are a part of the plates, they move in the exact same way as the plate moves.
  - C2 A plate's size and/or shape can be changed over time.
    - C2.1 An individual plate (and its continent if present) may split apart into two separate plates (and two separate continents) (e.g., South America and Africa were once part of the same plate, but were split apart [splitting is the explanation for the matching coastlines]); two plates with continents on each are sometimes pushed together and fused to form a larger plate (and larger continent). (e.g., India and Asia were at one time on separate plates but are fusing [were fused] together.)
  - C3 The speed or direction of plate motion can change over time.
  - C4 Abutting plates either move away from each other, toward each other, or alongside each other.
  - C5 When abutting plates move toward each other, material from one plate moves into Earth's interior.

D. Plate motions are driven by a combination of Earth's heat and gravitational forces. The consensus among geologists is that "slab pull," the sinking of oceanic plates at subduction zones (because that rock is old and relatively cold (dense)) is the primary driving force behind plate tectonics. Ridge push (the pushing forces exerted by elevated and relatively hot rock at mid-ocean ridges) is minor as is the traction along the bottoms of plates due to convection in the mantle.

E. Since the supercontinent Pangaea split up about 200 million years ago, the shapes of continents have been somewhat modified, mostly by erosion, sea level changes, and mountain-building; this is why the present-day "fit" of the continents is less than perfect.

F. Plate motion causes abutting plates to interact with one another along their boundaries resulting in observable geologic features and events.
  - F1 Prominent and distinctive *features* on Earth's surface include volcanoes, mountain ranges (volcanic & non-volcanic), deep ocean trenches, and mid-ocean ridges.
  - F2 *Events* are significant occurrences or happenings at a given place and time, such as earthquakes, volcanic eruptions, and mountain building.
  - F3 These geological features and events are most common at, or close to, the boundaries between two plates.

F3.1 Volcanoes, mountain ranges, and earthquakes can also occur in areas that are not near plate boundaries.

F4 Appendix 1 - The specific events and features that result from the different types of plate interactions are detailed in Appendix 1.

G. The occurrence of features and/or events at locations distant from plate boundaries are for reasons other than plate interactions (some volcanoes occur distant from plate boundaries as a result of hot spots)]

H. The rock that makes up plates is slowly being formed at some plate boundaries and returned to Earth's interior at other plate boundaries. This means that Earth is not changing in size.

H1 New rock from Earth's interior is continually added to the edges of plates that are moving away from one another. Because addition of rock and movement occur simultaneously, no noticeable gaps form between the plates.

H2 Older rock goes back deep into Earth's interior in places where one plate goes beneath another plate as they move towards one another.

H3 Appendix 2 - The specifics of what, where, and how rock is being recycled are detailed in Appendix 2.

I. The part of a plate with ocean floor along its boundary is always subducted beneath a plate with a continent along its boundary. Continental material is not subducted because of its low density. If continents on two separate plates are in contact and being pushed together, the continental rocks are forced upward forming mountain ranges rather than being completely subducted into Earth's interior. If two plates without continents are in contact and being pushed together, the colder/denser plate subducts beneath the other.

J. Old ocean floor rocks return by subduction into Earth's interior. Hence, ocean floor rocks are relatively young. Most continental rocks stay at Earth's surface because of their low density (although sediment eroded from the continents is carried to the oceans and can be subducted along with oceanic lithosphere). Hence, the age of some continental rock is quite old.

In addition to specifying the science content domain, HRI had envisioned the assessment to measure other kinds of knowledge. For instance, one could argue that teachers should know what misconceptions or prior conceptions students are likely to bring to a study of the content. Teachers should also know effective strategies for engaging students with the science content and for helping students make sense of the content. Finally, teachers should know effective strategies for informally assessing student understanding during instruction. Each of these types of knowledge, which Shulman (1987) dubbed "pedagogical content knowledge," is content-specific.

After a review of existing literature on pedagogical content knowledge (e.g., Carlsen, 1999; Magnusson, Krajcik, & Borko, 1999; Shulman, 1987; Veal and MaKinster, 1999; Wilson & Berne, 1999), HRI compiled seven content-specific domains of teaching knowledge (see Table 2). However, the research base in plate tectonics did not seem extensive enough to support item development in any domain but the first; i.e., item writers could use the literature to generate plausible distractors as well as a single correct answer. For example, although the research base in plate tectonics has identified some prevalent misconceptions, it is not strong enough to argue the *relative prominence* of two misconceptions. Further, it seemed unreasonable to expect teachers to be thoroughly familiar with the literature on student thinking in every content area they teach.

Table 2
Content-Specific Domains of Teacher Knowledge

1. **Knowledge of disciplinary content**
   This knowledge refers strictly to the science content, with no other elements of what a teacher would need to know in order to relate the content to students.

2. **Knowledge that alternative frameworks for thinking about the content exist**
   When teachers have deep knowledge of disciplinary content and recognize that different ways of organizing ideas exist, they can focus on helping students understand the important ideas, without necessarily requiring students to organize ideas in the exact same way. Such knowledge also enables teachers to recognize student understanding that is correct, but presented differently from how the teacher might organize it.

3. **Knowledge of the relationships between big ideas and the supporting ideas in a content area**
   Teachers need to help students not be so focused on the small details of the content that they never grasp the larger (and more powerful) concept.

4. **Knowledge/understanding of student thinking about the content**
   To help students understand content, teachers need to know what ideas students are *likely* to bring with them and where they are likely to struggle. Some content areas—e.g., force and motion—have a rich research base on student preconceptions and misconceptions, which includes research on how resistant these ideas may be to change. Most content areas do not have such a research base.

5. **Knowledge of activities/representations/hypothetical scenarios, etc. that can be used to *diagnose the thinking* of a particular group of students**
   Teachers need to know how to discern what ideas students have about a content area, both prior to and during a unit of instruction.

6. **Knowledge of how to sequence ideas for students to learn the content of interest**
   This type of knowledge highlights one of the differences in how a teacher and scientist think about content. A teacher needs to be able to think about content in terms of how students can most efficiently come to understand it. They need to know which ideas are pre-requisites for later ideas and how to progress from less complex to more complex ideas.

7. **Knowledge of content-specific strategies (activities/representations/hypothetical scenarios, etc.) that *move students' thinking forward***
   In addition to knowledge of student thinking, teachers need knowledge of ways to move that thinking forward. Included in this knowledge is an awareness that not all strategies will work equally well with all groups of students. The implications of some student differences are obvious—e.g., seeing or hearing impairments. Others are more subtle; e.g., representations that communicate well for students in inner city settings may not work well for students in rural schools, and vice-versa.

Multiple-choice items testing teachers' knowledge of instructional strategies were abandoned on different grounds. HRI recognized that the literature is not strong enough to judge the relative effectiveness of two or more activities that reasonably address the same idea. Interviews with teachers revealed that such items were not measuring knowledge, but rather they were measuring teachers' beliefs or attitudes about teaching.

In summary, the ATLAST Plate Tectonics Teacher Assessment measures only knowledge of science content.

3.2. Types of Teacher Assessment Items

The sections that follow discuss the three types of teacher multiple-choice items included in the assessment:

1. knowledge of science content (Level 1 items);
2. using content knowledge to analyze/diagnose student thinking (Level 2 items); and
3. using content knowledge to make instructional decisions (Level 3 items).

Knowledge of science content

All of the ATLAST items for teachers assess knowledge of science content, but the most basic type of question attempts to isolate disciplinary content knowledge from a teachers' ability to apply that knowledge in making instructional decisions. An example of these "Level 1" items is shown in Figure 3 (correct answer is A).

A teacher is reviewing some background information in preparation for a lesson on plate subduction. Which one of the following statements about subducting plates is a *correct* idea the teacher could include in her lesson?

A. The subducting plate has a *higher* density than the overriding plate.
B. The subducting plate has a *lower* density than the overriding plate.
C. The densities of the two plates are the same, but the subducting plate is *hotter* than the overriding plate.
D. The densities of the two plates are the same, but the subducting plate is *colder* than the overriding plate.

Figure 3
Level 1 Item

This item illustrates some features common to all ATLAST teacher assessment items. As mentioned previously, all of the items are multiple choice. In addition, all items include only four choices, and answer choices are never worded as "all of the above" or "none of the above." Multiple correct answers, such as "A and B but not C," are also not used. Perhaps most importantly, all of the items are set in an instructional context. The intent in using these contexts was two-fold: first, to make teachers feel like they were taking a test that was written for them, as opposed to, for example, a test constructed for undergraduates. The second goal was for teachers to recognize in the items the kind of work they do every day, making it more likely that they would intellectually engage with the items.

Using science content knowledge to analyze/diagnose student thinking

"Level 2" items require teachers to *apply* their content knowledge in analyzing or diagnosing a sample of student thinking. Figure 4 shows an illustrative item (correct answer is B).

During a class discussion about the supercontinent Pangaea, one student says,

> **"A long time ago, Pangaea broke up and the continents floated away from each other. Now the continents are all spread out all over Earth."**

Which one of the following is the best assessment of this student's response?

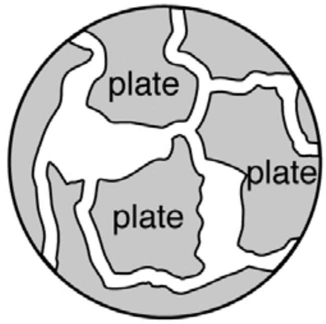
A. The student knows that Pangaea broke up, but does not understand that the continents are still moving today.
B. The student knows that the continents have moved over time, but does not understand that the continents moved only as the plates moved.
C. The student knows that the breakup of Pangaea took place a long time ago, but does not understand that new plate material has been formed since then.
D. The student knows the continents can move away from each other, but does not understand that they can move toward each other too.

Figure 4
Level 2 item

Certainly a teacher must understand the science content in order to answer Level 2 items correctly. However, additional analysis of the question is required because more than one of the choices includes a correct earth science statement, unlike the Level 1 item in Figure 3. In Figure 4, the statements in choices A, B, C and D are correct in terms of earth science, but only B *also* applies directly to what the student said. This feature is present in all Level 2 items and makes the cognitive load of these items higher than that of Level 1; teachers must evaluate the students' thinking in relation to the scenario in order to choose the correct answer.

Using content knowledge to make instructional decisions
"Level 3" items ask teachers to apply their content knowledge in choosing among instructional moves. A sample Level 3 item is shown in Figure 5 (correct answer is C).

When asked to draw a diagram of what Earth's plates look like, a student draws this diagram:



Based on the diagram, what question should the teacher ask to better assess the student's thinking about Earth's plates?

A. "In which direction are the plates moving?"
B. "How thick are the plates?"
C. **"What is between the plates in your diagram?"**
D. "Where were the plates ten million years ago?"

Figure 5
Level 3 Item

Level 3 items have the highest cognitive load, because teachers must not only evaluate the scenario, but also consider the student's thinking in relation to the scenario and then evaluate each instructional choice. As with Level 2 items, more than one answer choice has a correct earth science statement, but only one has a correct earth science statement *and* is relevant to the instructional context. Although the cognitive load of Level 3 items is demanding, it is a small fraction of the demand placed on a teacher managing the learning of a classroom of students.

3.3. Item Development

Development of the multiple-choice items began with asking approximately 65 teachers to respond to open-ended items about the teaching of plate tectonics concepts. A sample item is shown in Figure 6. These items accomplished two things. First, responses to these items provided a window into teachers' thinking about the content, in many cases revealing the kinds of misconceptions teachers have about plate tectonics. In most instances, their misconceptions were the same as those identified in the literature as held by middle grades students. Second, teachers' incorrect responses could be used to generate distractors for the multiple-choice items.

During a discussion about plate tectonics, a teacher asks her students “Are Earth’s plates moving today?” One student says,

> **“Earth’s plates moved when Pangaea broke apart, but they are not moving today.”**

What aspects, if any, of this student’s response are correct and what aspects, if any, are incorrect?

What could this teacher do to help move this student forward in his thinking about the movement of Earth’s plates?

Figure 6
Open-Ended Item Used in Development

Once teachers’ responses to open-ended items were collected, a months-long iterative process followed in which multiple-choice items were written and refined based on conducting cognitive interviews with middle grades science teachers. The interview protocol is shown in Figure 7.

Prologue:

We are developing a test for middle school teachers who teach earth science, and we need your help to get the questions on the test just right. I don't expect you to answer all of the answers correctly. If you get a few wrong, it will help me know whether we have written the items well. Remember, the point is to help us write a good test, not to test what you do or don't know. Do you have any questions before we get started? Remember that all of your answers are confidential.

Procedure:

- Ask teacher to read aloud and "think aloud" as they read the questions and answer choices, if they are comfortable doing so.

- For each multiple-choice item, ask:
  1. Why did you choose that answer? (probe for words or diagrams they keyed in on, as well as their thinking behind the response)
  2. Were there other answer choices that you almost chose? (why?)
  3. Were there any answer choices that you did not even consider? (why?)
  4. Was there an answer choice you were expecting to see, but did not? What was it?
  5. Were there any words or diagrams you did not really understand, or situations that made the question confusing?
  6. Do you have any other comments on the item?

Figure 7
Cognitive Interview Protocol

The cognitive interviews revealed distinct patterns of errors in teacher responses to the Level 2 items (using content knowledge to analyze/diagnose student thinking). Some teachers chose an answer that included student thinking they were familiar with, whether or not it represented the thinking of the student in the item. Others chose a statement that was correct in terms of plate tectonics, but not in relation to the student's thinking.

Interviews also suggest some common errors teachers make with Level 3 items (using content knowledge to make instructional decisions). First, they often saw more than one of the instructional choices (including the correct one) as equally good. Teachers have an especially difficult time choosing an answer when the item requires teachers to evaluate which question should be asked next. When the choices are about actual activities, teachers sometimes get bogged down in the details of the choices. For instance, they may rule out a choice because they do not have access to the materials, regardless of whether the activity would help move the student's thinking forward. Finally, teacher beliefs about effective instruction may get in the way, even when they seem to understand the content targeted by the item. For example, teachers often choose a hands-on activity, even if it does not address the student's thinking.

3.4. Field Tests

A pool of approximately 75 plate tectonics teacher items was distributed over three forms for the initial pilot test, with several linking items common to each form. Over 500 middle grades science teachers across the nation responded to each item. Each group included roughly 10 percent high school earth science teachers to ensure an adequate distribution of levels of teacher knowledge in the sample. The remaining respondents were middle grades science teachers.

Using results from the first field test, 35 items were selected for the second field test with approximately 700 teachers nationally, with approximately one-tenth of the sample being high school science teachers. Table 3 describes the sample in terms of various demographic variables. Both field tests were administered entirely on-line.

Table 3
Characteristics of the Second Field Test Sample (N = 709)

	Percent
Experience Teaching Plate Tectonics	
Middle school earth science	62
Middle school integrated earth science	54
High school earth science	10
High school AP environmental earth science	1
Other	5
Taken a college-level introductory geology course	73
Gender	
Female	71
Male	29
Race/Ethnicity	
American Indian or Alaskan Native	1
Asian	2
Black or African American	3
Hispanic or Latino	2
Native Hawaiian or Other Pacific Islander	0
White	93

4. Measurement Properties of the Assessment

Following is a description of the content coverage of the assessment, information about the validity and reliability of the assessment, and the results of the item-response theory (IRT) analysis.

4.1. Content Coverage

Using results from the second field test, 30 items were selected for the final form. The distribution of items by sub-idea is shown in Table 4. The number of items totals to more than 30 because one item may address more than one sub-idea.

Table 4
Number of Items Addressing Each Sub-Idea

Sub-Ideas:	Number of Items
A. The solid outer portion of Earth consists of separate plates of almost entirely solid rock. A1 Plates abut other plates on all sides. There are no visible gaps between plates that are adjacent to each other. A2 The upper portions of some of Earth's plates are the continents and some seafloor beneath the oceans. A3 The rest of Earth's plates do not include continental material but only seafloor beneath the oceans. A4 There are 10–12 *major* plates. Major plates are larger than some continents; plates can be thousands of kilometers across. Plates average 100 km thick, which is $^{1}/_{60}$ of Earth's radius. A5 Plates are on top of solid, slightly softened rock. They do not float or move on molten rock or water.	6
B. Earth's plates (the lithosphere or lithospheric plate) are cold (relative to deeper portions of Earth), strong and brittle and average about 100 kilometers in thickness. Beneath the lithosphere is an almost entirely solid (~99%) layer of Earth (the asthenosphere) which is hot, weak and plastic and extends from the base of the lithosphere to a depth of about 350 kilometers.	2
C. The plates that make up Earth's surface are constantly moving and changing. C1 All of Earth's plates move very slowly (a few centimeters per year). C1.1 Since the continents are a part of the plates, they move in the exact same way as the plate moves. C2 A plate's size and/or shape can be changed over time. C2.1 An individual plate (and its continent if present) may split apart into two separate plates (and two separate continents) (e.g., South America and Africa were once part of the same plate, but were split apart [splitting is the explanation for the matching coastlines]); two plates with continents on each are sometimes pushed together and fused to form a larger plate (and larger continent). (e.g., India and Asia were at one time on separate plates but are fusing [were fused] together.) C3 The speed or direction of plate motion can change over time. C4 Abutting plates either move away from each other, toward each other, or alongside each other. C5 When abutting plates move toward each other, material from one plate moves into Earth's interior.	6
D. Plate motions are driven by a combination of Earth's heat and gravitational forces. The consensus among geologists is that "slab pull," the sinking of oceanic plates at subduction zones (because that rock is old and relatively cold [dense]) is the primary driving force behind plate tectonics. Ridge push (the pushing forces exerted by elevated and relatively hot rock at mid-ocean ridges) is minor as is the traction along the bottoms of plates due to convection in the mantle.	1
E. Since the supercontinent Pangaea split up about 200 million years ago, the shapes of continents have been somewhat modified, mostly by erosion, sea level changes, and mountain-building; this is why the present-day "fit" of the continents is less than perfect.	2
F. Plate motion causes abutting plates to interact with one another along their boundaries resulting in observable geologic features and events. F1 Prominent and distinctive features on Earth's surface include volcanoes, mountain ranges (volcanic and non-volcanic), deep ocean trenches, and mid-ocean ridges. F2 Events are significant occurrences or happenings at a given place and time, such as earthquakes, volcanic eruptions, and mountain building.	5

F3 These geological features and events are most common at, or close to, the boundaries between two plates. F3.1 Volcanoes, mountain ranges, and earthquakes can also occur in areas that are not near plate boundaries. F4 The specific events and features that result from the different types of plate interactions are detailed in Appendix 1.	
G. The occurrence of features and/or events at locations distant from plate boundaries are for reasons other than plate interactions (some volcanoes occur distant from plate boundaries as a result of hot spots).	1
H. The rock that makes up plates is slowly being formed at some plate boundaries. Rock that makes up the plates is returned to Earth's interior at other plate boundaries. This means that Earth is not changing in size. H1 New rock from Earth's interior is continually added to the edges of plates that are moving away from one another. Because addition of rock and movement occur simultaneously, no noticeable gaps form between the plates. H2 Older rock goes back deep into Earth's interior in places where one plate goes beneath another plate as they move towards one another. H3 The specifics of what, where, and how rock is being recycled are detailed in Appendix 2.	5
I. The part of a plate with ocean floor along its boundary is always subducted beneath a plate with a continent along its boundary. Continental material is not subducted because of its low density. If continents on two separate plates are in contact and being pushed together, the continental rocks are forced upward forming mountain ranges rather than being completely subducted into Earth's interior. If two plates without continents are in contact and being pushed together, the colder/denser plate subducts beneath the other.	2
J. Old ocean floor rocks return by subduction into Earth's interior. Hence, ocean floor rocks are relatively young. Most continental rocks stay at Earth's surface because of their low density (although sediment eroded from the continents is carried to the oceans and can be subducted along with oceanic lithosphere). Hence, the age of some continental rock is quite old.	1

Table 5 shows the answer key and content association for each item on the assessment. The letter "P" denotes a primary association with the sub-idea being targeted by the item. An "s" denotes a secondary association with a sub-idea that is also necessary in order to answer the item correctly but is not the primary idea being assessed.

Table 5
Answer Key and Sub-Idea Associations

Item #	Key	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
1	A	P									
2	C	P									
3	B			P							
4	D					P					
5	A								P		
6	B			P							
7	B								P		
8	A	P									
9	B	P									
10	A		P								
11	C	P									
12	C								P		
13	B						P				
14	C						P				
15	D		P								
16	A			P							
17	A									P	
18	A					P				s	
19	D								P		
20	D			s	P						
21	C						P				
22	B									P	
23	D								P		
24	D			P							
25	C	P									
26	B										P
27	C			P							
28	D						P	P			
29	B						P				
30	B			P							
Primary:		6	2	6	1	2	5	1	5	2	1
Secondary:		0	0	1	0	0	0	0	0	1	0
Total:		6	2	7	1	2	5	1	5	3	1

4.2 Validity

Four lines of evidence support the argument that the assessment is a valid measure of teachers' knowledge of plate tectonics ideas. First, cognitive interviews with teachers established that teachers interpret the items as intended and that teachers must use their knowledge of content to answer the items correctly. Second, a panel of three content experts (individuals with a Ph.D. in geology) reviewed the assessment items at three stages (see Figure 2) to ensure content accuracy. They also reviewed the final assessment and judged it to be an adequate measure of the content domain. Third, dimensionality analyses (including both factor analysis and cluster analysis) indicate that all items on the assessment measure a single dominant trait. HRI termed this trait "content knowledge for teaching about plate tectonics."

A fourth line of evidence for the validity of the assessment is derived from a study that compared teachers' performance on the assessment with their knowledge level as indicated in an interview. HRI administered the assessment to approximately 100 middle grades teachers. The five highest- and lowest-scoring teachers were selected for interviews. Interviews were conducted approximately two months after the assessment by a content expert (a Ph.D. geology professor). The interviewer was not aware of the teachers' assessment scores. Interview questions addressed the same content used to formulate the assessment and were developed through the collaboration of HRI researchers with the content expert. The interview provided a second measure of content knowledge, independent of the assessment with regard to format and time of administration.

Based on the interview responses, the content expert categorized each interviewee as displaying "extensive knowledge of the content" or "limited knowledge of the content." Analysis of the interviewer ratings and assessment scores showed that the five highest-scoring teachers were categorized as having "extensive knowledge of the content," while the five lowest-scoring teachers were categorized as having "limited knowledge of the content." The agreement between assessment score and interviewer rating provides further evidence that the assessment is a valid measure of teachers' knowledge of plate tectonics ideas.

4.3 Reliability

The assessment has an internal reliability of 0.86. HRI conducted a study of test-reliability with approximately 100 middle grades science teachers who took the test twice, two weeks apart with no intervening instruction. The test-reliability was calculated to be 0.94.

4.4 Speededness

Neither the pilot, field test, nor test-retest study were timed administrations. As such, there is no information about speededness.

5. Using the Assessment

The ATLAST Plate Tectonics Teacher Assessment is available at no cost to individuals who agree to certain terms of use. To request a review copy of the assessment, or to access the terms of use, visit http://www.horizon-research.com/atlast.

5.1. Appropriate Use

The ATLAST Plate Tectonics Teacher Assessment will yield a score for each individual. However, the assessment is not valid for making *judgments* about individuals based on those scores. For instance, assigning grades based on scores is not a valid use of the assessment. The assessment was not validated for such purposes.

HRI developed the assessment for use in research contexts involving groups of teachers. Appropriate uses with sufficiently large groups of teachers (20 or more) include:

- Measuring the change in group mean from pre-workshop to post-workshop;
- Comparing the gains of treatment and control groups; and
- Investigating the relationship between teacher knowledge and student learning.

5.2. Amount of Time Required to Complete the Assessment

As described above, both the pilot and field test were administered on-line and were not timed. Although there is no evidence of speededness, it is recommended that at least 30 minutes be allowed for completing the assessment.

5.3. Computing Scores

Raw scores may be computed either as number correct or percent correct. Results of an item-response theory (IRT) analysis are shown in Table 6. This table can be used to convert a raw score in terms of number correct to the corresponding scaled score. Raw and scaled scores representing mean values are presented in bold text.

Table 6
Assessment Score Conversions

Plate Tectonics Teacher Assessment				
RawScore	Scaled Score		Raw Scores	
0	5		Mean	SD
1	7		20.8	5.72
2	10			
3	13			
4	15			
5	18			
6	21			
7	25			
8	26			
9	28			
10	32			
11	37			
12	41			
13	43			
14	46			
15	51			
16	53			
17	55			
18	60			
19	64			
20	67			
21	**69**			
22	73			
23	76			
24	80			
25	83			
26	88			
27	91			
28	94			
29	97			
30	100			

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Appendix 1 (Idea F4)
Relative Plate Motion/Plate Interactions of Two Abutting Plates

	Plates moving away from one another	**Plates Moving Toward One Another**		**Plates moving alongside one another**	**Implication**
		With no continents or a continent on only one of the plates	**With continents on both plates**		
Typical Events*					The unique combination of features and events provides evidence of certain types of plate interactions in a given area.
Earthquakes**	X	X	X	X	
Volcanic eruptions**	X	X	[2]		
Mountain building	X (volcanic)	X (volcanic)	X (non-volcanic)		
Typical Features*					
Volcanoes	X	X			
Volcanic mountain range on land or a series of volcanic islands[3]	***	X			
Mid-ocean ridge (mostly underwater volcanic mountain range)	X				
Non-volcanic mountain range			X		
[Rifts/rift valleys]	X				
[Deep sea trench]		X			
[Faults/Fault lines]	X	X	X	X	

[Teacher ideas are in brackets.]

X Event/feature typically occurs at this location.

* Events/features not included in these lists are not a direct result of plate interactions.

** Volcanoes and earthquakes are associated with one another (found in the same areas) because they are caused by same types of plate interactions. Earthquakes don't cause volcanoes, and volcanoes do not cause most earthquakes. [Earthquakes can indicate volcanic activity. A volcanic eruption (especially violent eruptions) can lead to earthquakes, although not major earthquakes.]

******* A cell that is blank in this table means that this event/feature is not typically found along that type of boundary. A few exceptions exist.

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2 As two continents are pushed together, some limited amount of molten rock can be formed, but such formation rarely results in volcanoes or volcanic eruptions.

3 Examples are Japan and other island arcs that formed by volcanic activity. The Hawaiian Islands are not an island arc—they are volcanic, but they are not near a plate boundary. Instead, the Hawaiian Islands formed over a hot spot under the Pacific plate.

Appendix 2 (Idea H3)
The Recycling of Plate Material (Rock) Along Plate Boundaries

Recycling	Plates moving away from one another	Plates Moving Toward One Another: With no continents or a continent on only one of the plates	Plates Moving Toward One Another: With continents on both plates	Plates moving alongside one another	Implication
New material (rock) from Earth's interior is added to both plates along their shared boundary (edge).	X				Plate material is added to plates in some places and removed from other places→ Earth's size remains constant.
Plate material (rock) that is sliding beneath another plate is removed from Earth's surface and becomes part of Earth's interior.		X			
Continental plate material usually is not recycled. Instead, most of the rock that makes up the continents is pushed together and forced upward to form mountains; the plates may fuse and form a larger plate.			X		

Terms of Use Agreement
Plate Tectonics Teacher Assessment

By using the ATLAST Plate Tectonics Teacher developed by Horizon Research, Inc. (HRI), you agree to abide by the stipulations below concerning use, test security, test administration, and citations.

Use of the Assessment

The Plate Tectonics Teacher assessment may be used to gauge growth in knowledge about a specific content area as a result of an intervention such as professional development, curriculum use, or mentoring. It may also be used to learn about the contribution of teacher knowledge to student knowledge and classroom instruction.

We ask that you abide generally by the standards put forward in the *Standards for Educational and Psychological Testing* (AERA/APA 1999).

You may not use the assessment to evaluate individuals. Assessment results may not be associated with any high-stakes consequence such as tenure, pay, hiring, or grades. The assessments were not developed for making decisions/judgments about individuals.

You should also refrain from using these measures to publicly demonstrate teachers' ability or lack of ability in science, which may adversely affect willingness to participate in future studies.

IRB and/or District/School Study Approval

It is your responsibility to obtain proper IRB and/or the appropriate district/school approval for your study and to follow the necessary requirements for obtaining principal, teacher, parent, and/or student permission/approval to administer to the assessment(s).

Responsibilities to Teachers and Students

Your responsibilities to study participants will largely depend on the details of the IRB and/or district/school approval of your study. In most cases, completion of the assessment will be strictly voluntary. As such, participants should be informed of the voluntary nature of the study. Teachers should be assured that if their data are not anonymous, individual identities will be kept strictly confidential; i.e., an individual's score or responses will never be reported in association with his or her name or any other identifying information. To encourage a high response rate among teachers, it may be helpful to:

- Clearly explain what the data will be used for and why the data are important for your study;
- Explain that there are no high-stakes consequences associated with completing the assessment;

- Offer teachers compensation for time spent outside of the regular school day completing the assessment.

Test Security

The ATLAST Plate Tectonics Teacher Assessment may NOT be shared without prior authorization from HRI. Anyone who administers the assessment must agree to:

- Refrain from using any non-released item in any presentation, paper, article, or other public forum. Items are expensive to develop and pilot, and we are attempting to keep our item pool secure.
- Refrain from distributing copies of any non-released item to individuals other than participants in your research project.
- Refrain from using the assessment, in original or in copied form, to provide test-taking practice or to enhance test-taking skills.
- Refrain from using test items, actual or similar, for discussion or review.

(HRI acknowledges that, in some cases, school administrators and IRBs may require that the test materials be reviewed prior to granting permission for study participants to take the test. Such a review is not considered a violation of this Test Security Policy as long as the other provisions of this policy are not violated.)

Citing ATLAST Assessments

In any writing in which data from HRI's ATLAST assessments are included, the following citation must be used:

The assessment was developed by the Assessing Teacher Learning About Science Teaching (ATLAST) project at Horizon Research, Inc. ATLAST is funded by the National Science Foundation under grant number DUE-0335328.

By signing below, I acknowledge that I have read the user manual, and I agree to abide by terms of use described above.

____

Printed Name Signature Date

Address: ____

Street City State Zip code

Phone number (including area code): ____________________________________

Your email address: ____