ATLAST Plate Tectonics Student Assessment
User Manual

1. Overview

The ATLAST Plate Tectonics Student Assessment is a 30-item multiple-choice assessment for middle grades students. 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 Force and Motion Student 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 a 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.

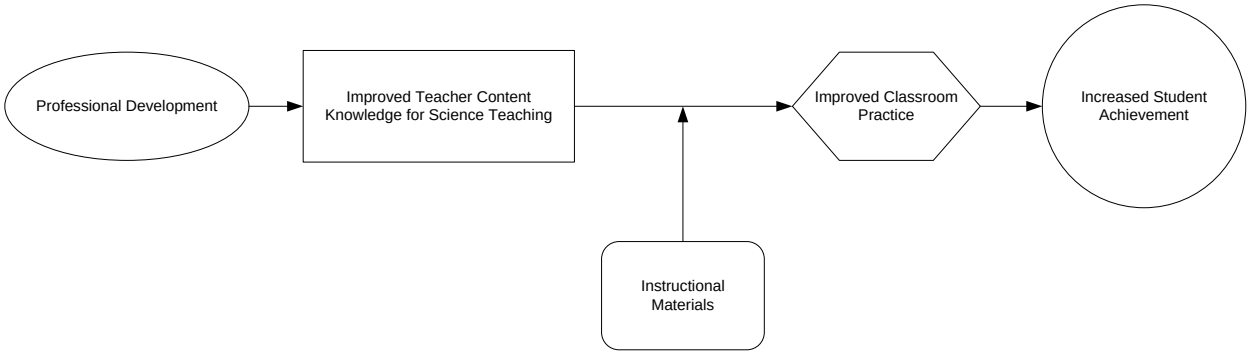

Figure 1
ATLAST Theory of Action

To enable large-scale research, HRI set out to create assessments that would be minimally burdensome, for both 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 Student Assessment

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

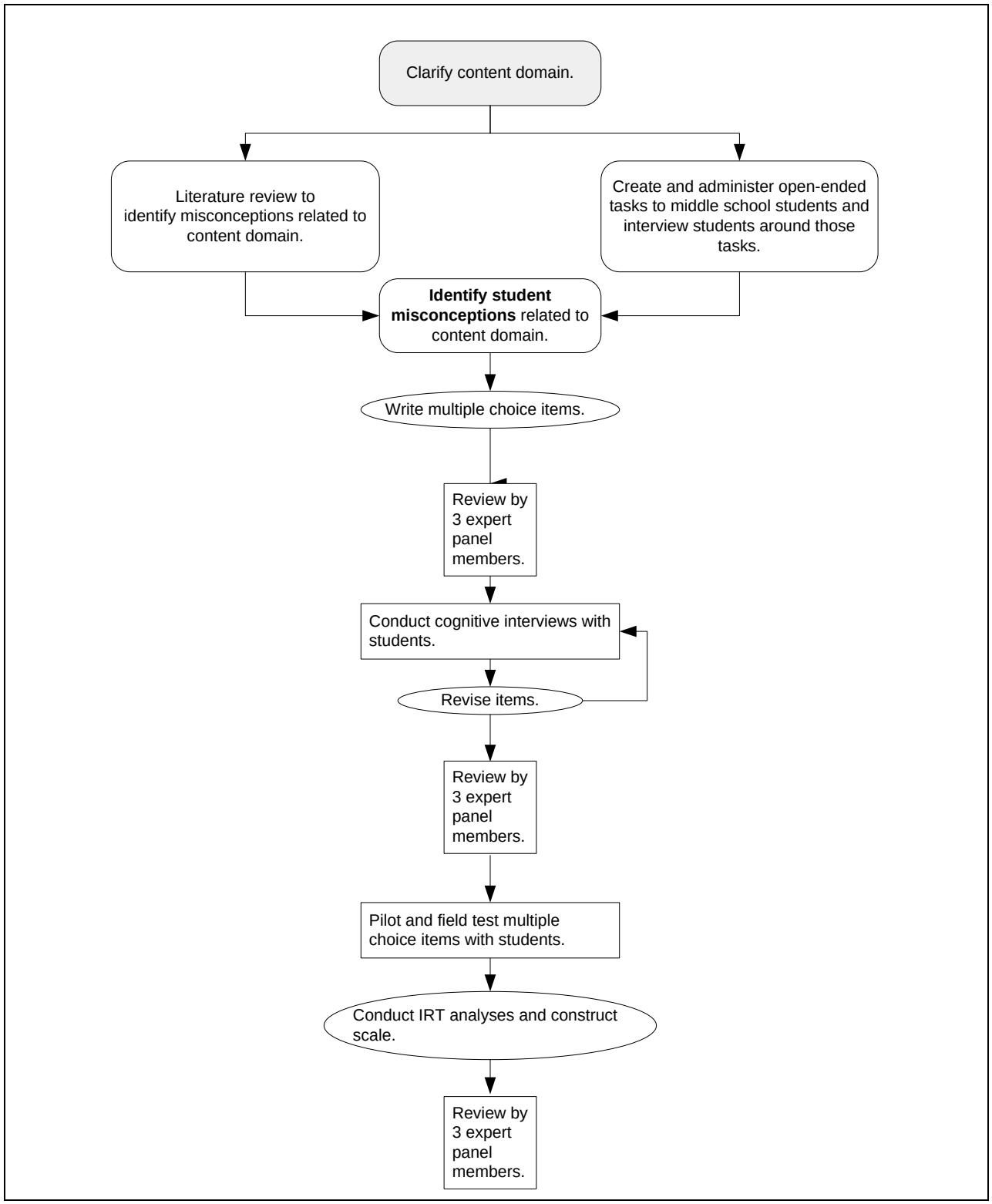

Figure 2
ATLAST Assessment Development Process

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," which were reviewed by four geologists/geology educators, resulting in minor edits. The final description of the content domain is shown in Table 1. Note that for students, the content domain includes only four sub-ideas.

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 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.
   - 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).*

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.

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 to the mantle 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.*

* These sub-ideas are for teachers only; they are not assessed at the student level.

3.2 Item Development

Development of the multiple-choice items began with identifying student misconceptions in the area of Plate Tectonics. Although there is a substantial amount of literature on student misconceptions for some science content areas, including Force & Motion, there was a relatively small amount of literature for Plate Tectonics. Thus in addition to gleaning student misconceptions from the literature, we administered open-ended tasks through interviews with students to characterize student thinking related to this content area. Several students were interviewed about a series of open-ended items that address the student-level sub ideas shown in Table 1. Student interview responses served as a basis for describing relevant student thinking. An extensive list of student pre-conceptions and misconceptions was developed and then each area of difficulty was associated with one or more of the sub-ideas. Figure 3 shows the student ideas associated with *one* sub-idea.

Sub-idea	Student pre-conceptions and misconceptions
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.	• "New" rock is created when a large rock is broken into smaller pieces – the smaller pieces are the "new" rock. • All rock on Earth is the same age. • New rock is added to plates primarily from the top when volcanoes spew out molten rock that solidifies into new rock on the surface of the plate. • The subduction of plates means that Earth is becoming smaller. • The continual formation of new rocks that are under the ocean (ocean floor) means that Earth must be getting larger.

Figure 3: A Plate Tectonics Sub-idea with Associated Research on Student Thinking

After identification of relevant student misconceptions, a months-long iterative process followed in which multiple-choice items were written and refined based on input from cognitive interviews with middle grades students. The interview protocol is shown in Figure 4.

Prologue:

We are developing test questions for middle school students who have been studying plate tectonics, and we need your help to get the questions just right. I realize that you may not have studied some of this yet in school, and I don't expect you to get all of the answers right. If you get a few wrong, it will help me know whether we have written the answer choices well. You can ask me to explain any words or situations that may be unfamiliar or confusing, but I can't give you the answer to any of the questions until the end of the interview. Remember, the point is to help us write a good test, not to test what you do or don't know. You won't get a grade or anything like that on the test. Do you have any questions before we get started? If at any point in the interview you would like to stop, just say so.

Procedure:

- Ask student to read aloud and "think aloud" as they read the questions and answer choices, if they are comfortable doing so. Remind the student to go back and reread the question to himself/herself if he/she needs to. If reading the question aloud is too distracting or uncomfortable, allow the student to read the question to himself/herself.

- It is not necessary to time how long it takes for the student to arrive at an answer, but if it takes an especially long time on a question, please make a note of it in the comment area of the notes.

- For each 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. What did you think of each of the other answer choices? (why?)
  3. Was there an answer choice you were expecting to see, but did not? What was it?
  4. Were there any words or diagrams you did not really understand, or situations that made the question confusing?
  5. Is there anything about the question that did not confuse you, but that you think might confuse other middle school students?

Figure 4
Cognitive Interview Protocol

An example student assessment item resulting from this process is shown in Figure 5.

Which one of the following statements about the size of Earth is true?

A. Earth is getting bigger because new plate material is being added.
B. Earth is getting smaller because plate material is going back into Earth's interior.
C. Earth's size is *not* changing because plates don't move.
D. Earth's size is *not* changing because plate material is added in some places and removed in others.

Figure 5
Plate Tectonics Item

This item illustrates some features common to all ATLAST teacher assessment items. As mentioned previously, all are multiple choice. All include only four choices and preclude as choices "none of the above," "all of the above," or multiple correct answers such as, "A and B but not C."

3.3 Field Tests

A pool of 69 plate tectonics student items were included in a pilot test. Approximately 4000 middle school students across the nation responded. Review of the responses and analysis of the data suggested that some items be omitted and others revised. The revised items were developed through the same process as the original items.

Using results from the pilot test and including revised items, we conducted a field test using 35 items with approximately 4,000 students nationally.

For both the pilot and the field test, HRI recruited middle school science teachers to administer the items to at least one of their classes. Table 2 describes the final field test sample in terms of various demographic variables.

Table 2
Characteristics of the Field Test Sample (N = 3997)

	Percent
Grade Level	
6th	21
7th	32
8th	48
Gender	
Female	49
Male	51
Race/Ethnicity	
American Indian or Alaskan Native	5
Asian	5
Black or African American	15
Hispanic or Latino	19
Native Hawaiian or Other Pacific Islander	2
White	68
English Language Learner	10

4. Measurement Properties of the Assessment

We include in this section: 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 field test, 30 items were selected for the final form. The distribution of items by sub-idea is shown in Table 3. The number of items totals to more than 30 because one item may address more than one sub-idea.

Table 3
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.	8
C. The plates that make up Earth's surface are constantly moving and changing.	8
F. Plate motion causes abutting plates to interact with one another along their boundaries resulting in observable geologic features and events. .	8
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.	7

Table 4 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 4
Answer Key and Sub-Idea Associations

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

4.2 Validity

Three lines of evidence support the argument that the assessment is a valid measure of students' knowledge of plate tectonics ideas. First, cognitive interviews with students established that students interpret the items as intended and that students 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. Finally, dimensionality analyses (including both factor analysis and cluster analysis) indicate that a 1-factor solution was supported. HRI termed this factor "content knowledge about plate tectonics."

4.3 Reliability

The assessment has an internal reliability of 0.86

4.4 Speededness

In the field test, teachers were instructed to give their students 50 minutes or the length of the class period (whichever was shorter) to complete the test. There was no evidence of speededness.

5. Using the Assessment

The ATLAST Plate Tectonics Student 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. The terms of use are also appended to this manual. Descriptions of appropriate assessment uses and score calculations are presented below.

5.1 Appropriate Use

The ATLAST Plate Tectonics Student 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 students. Appropriate uses with sufficiently large groups of students (20 or more) include:

- Measuring the change in group mean from pre-instruction test to post-instruction test;
- 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

Although there is no evidence of speededness, it is recommended that at least 45 minutes be allowed for completing the assessment.

5.3 Computing Scores

Scores may be computed either as number correct or percent correct. Results of an item-response theory (IRT) analysis are shown in Table 5. 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 5
Assessment Score Conversions

Plate Tectonics Student Assessment			Raw Score	
RawScore	Scaled Score		Mean	SD
0	5		14.8	6.15
1	8			
2	9			
3	11			
4	13			
5	15			
6	17			
7	20			
8	23			
9	26			
10	30			
11	33			
12	37			
13	41			
14	46			
15	**50**			
16	54			
17	56			
18	59			
19	63			
20	67			
21	70			
22	74			
23	77			
24	80			
25	83			
26	87			
27	91			
28	93			
29	97			
30	100			

References

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Terms of Use Agreement
Plate Tectonics Student Assessment

By using the ATLAST Plate Tectonics Student 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 Student Assessment may be used to gauge growth in knowledge about a specific content area as a result of instructional experiences.

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 grades. The assessments were not developed for making decisions/judgments about individuals.

You should also refrain from using these measures to publicly demonstrate students' 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. Students 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;
- If applicable, offer teachers compensation for time spent outside of the regular school administering the assessment.

Test Security

The ATLAST Plate Tectonics Student 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: _____