AIM User Manual
Populations and Ecosystems
Elementary School Teacher Assessment

Overview

The AIM Populations and Ecosystems Elementary School Teacher Assessment is a 30-item multiple-choice assessment developed for teachers of elementary grades science. The assessment is based on the *Science Framework for the 2009 National Assessment of Educational Progress* (National Assessment Governing Board, 2008) and measures understandings of selected concepts in a single content area: the interdependence of organisms and specific types of interdependence.

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

Background

Horizon Research, Inc. (HRI) developed the AIM Populations and Ecosystems Teacher Assessment as part of a larger study. The project—Assessing the Impact of the MSPs: K–8 Science (AIM) was funded by the National Science Foundation under Grant no. DUE-0928177.[1] One goal of AIM 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, AIM developed pairs of assessments—one for teachers and one for students—focused on the same science content areas. These pairs of assessments enable the study of relationships between teacher knowledge and student learning in specific science contexts. AIM assessments exist for four content areas: (1) evolution and diversity of life; (2) force and motion (Newton's first and second laws); (3) populations and ecosystems; and (4) properties of and changes in matter. For each content area, separate pairs of assessments were developed for elementary school and middle school levels.

[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.

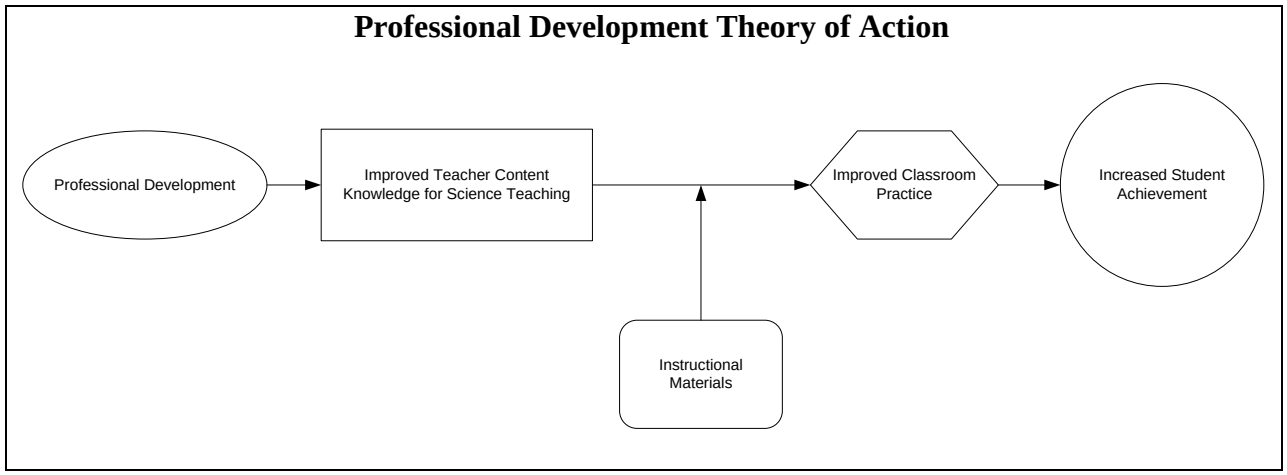

Figure 1

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.

Development of the Populations and Ecosystems Elementary School Teacher Assessment

As described above, this development effort was part of a much larger and well-funded project, which afforded a thorough development process (see Figure 2).

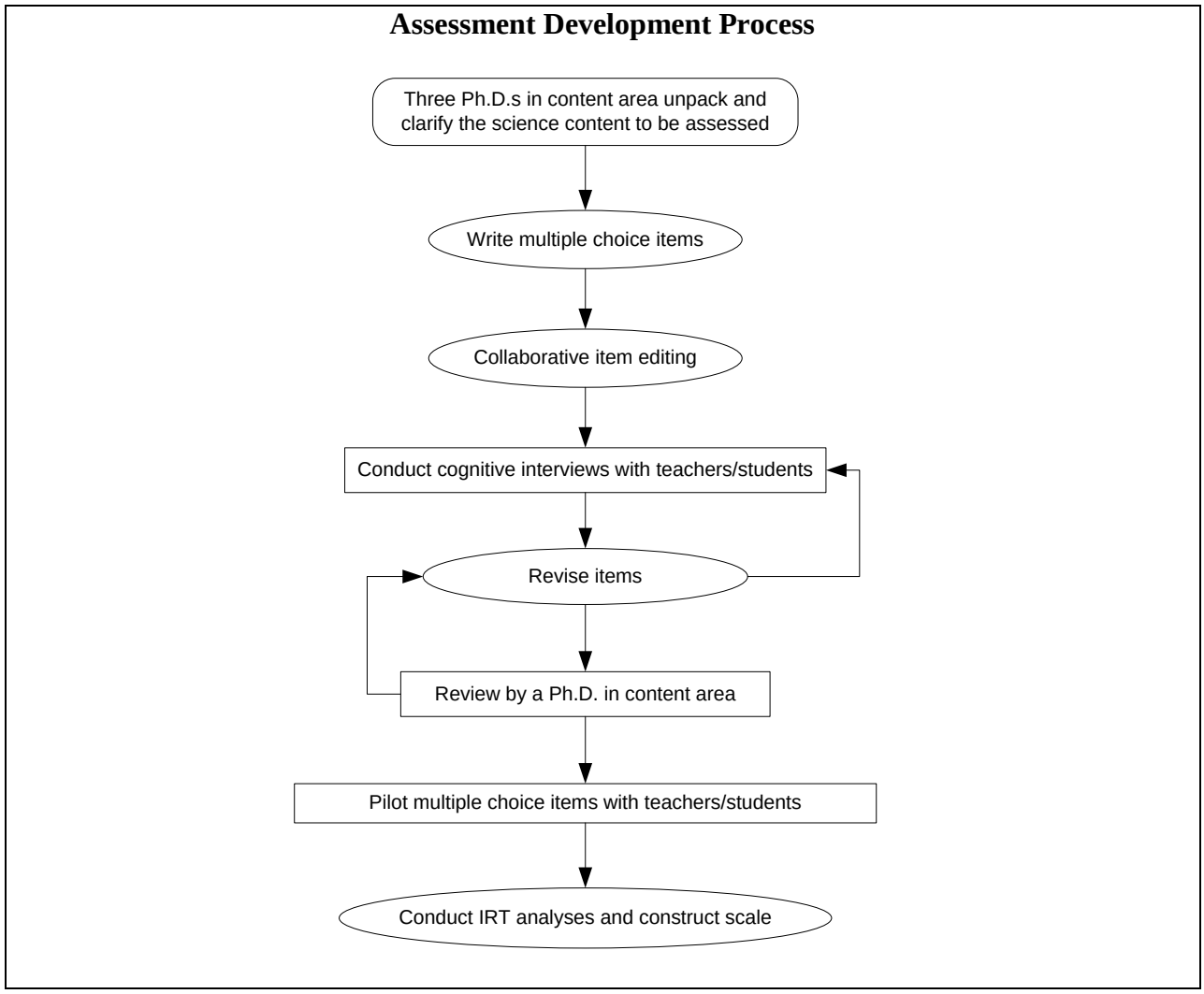

Figure 2

Clarifying the Content Domain

Development began with identifying the target content for the populations and ecosystems assessments. We used the 2009 *NAEP Framework* (National Assessment Governing Board, 2008) for direction on the content of the AIM assessments. The *NAEP Framework* was based primarily on the *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), but also reflected developments in science and policy that have taken place since those documents were published. HRI specified the assessment domain using a single strand in the *NAEP Framework*: the interdependence of organisms and specific types of interdependence. This process had three biologists/biology educators "unpack" the content into series of "sub-ideas" for elementary school students. Additional sub-ideas that are important for teachers to understand in order to teach the elementary school student ideas were also specified by the content experts. Both sets of ideas were considered in developing the elementary school teacher assessment. The final description of the content domain is shown in Table 1.

Table 1a
Populations and Ecosystems Content Domain

Populations and Ecosystems. The interdependence of organisms and specific types of interdependence

Sub-ideas for students:

- Organisms interact and are interdependent in various ways, including providing food and shelter to one another.
  - An organism is any living thing, such as a plant or an animal. Organisms are categorized by how they get their food.
  - Organisms depend on other organisms for food and/or nutrients.
  - In some interactions, both organisms benefit by interacting and are more likely to survive and reproduce.
  - In some interactions, one organism will benefit by interacting and is more likely to survive and reproduce while the other is harmed and its survival and/or reproduction may be limited.
- Organisms can survive only in environments in which their needs are met.
  - Each type of organism has a specific range of environmental conditions under which it can survive. Environmental conditions include, but are not limited to, temperature, moisture, amount of oxygen, nutrient availability, and salinity.
- Some interactions are beneficial; others are detrimental to the organism and other organisms.
- When the environment changes, some plants and animals survive and reproduce; others die or move to new locations.
  - An organism's environment includes all of the living and non-living things that surround and influence the organism.
  - Organisms have different traits; some traits are better than others for a given environment (i.e., help the organism meet its needs).
  - Organisms with traits that are favorable in an environment are more likely to survive and reproduce, whereas organisms that lack those traits are less likely to survive and reproduce.
  - Organisms, including humans, often change the environment in which they live through feeding, leaving waste, and/or competing with other organisms.
  - Sometimes, environments change and no longer provide for the needs of some or all of the organisms that live there. Some organisms will be able to survive in the new conditions, some will move to a new environment where their needs are met, and some will not survive.

Table 1b
Populations and Ecosystems Content Domain

Populations and Ecosystems. The interdependence of organisms and specific types of interdependence

Sub-ideas for teachers:

- Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or, one organism may scavenge or decompose another.
  - Producers, including green plants and algae, are the primary food source within an ecosystem.
  - Food webs illustrate the feeding relationships between producers and consumers and among consumers in an ecosystem.
- Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.
  - Sometimes, organisms compete with each other for food and resources.
  - Competitive relationships exist when multiple organisms rely on the same resource(s).
  - Mutually beneficial relationships (mutualisms) exist when organisms interact and both or all are more likely to survive and/or reproduce.
  - Co-evolution occurs when more than one species have existed together long-term, influencing changes in each other.
- The number of organisms and populations an ecosystem can support depends on the biotic resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition.
  - All populations living together and the physical factors with which they interact compose an ecosystem.
  - A population is a group of individuals of the same species that live and breed together in a particular area.
  - Organisms compete for limited resources. Populations of organisms can potentially grow unchecked, but tend to remain the same size because of limited resources.
  - When organisms compete, often only some organisms survive because they are better adapted for acquiring resources in that environment.
  - Population density in an area varies from time to time based on variation in availability of nutrients, weather, and presence of other organisms.
- All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organisms or other organisms, whereas others are beneficial.
  - The mix of species in a given environment changes in response to a changing environment over time.
  - Ecological succession occurs in areas where there have previously been no organisms (e.g., weathering rock) or where prior life has been removed or reduced (e.g., volcanoes, fire). Pioneer organisms change the environment in ways that make it possible for other organisms that could not previously survive in the environment to live there. Organisms successively change the environment, making it more suitable for other organisms.
  - Some organisms can change their environment to the extent that their offspring can no longer live there. This area becomes better suited to other organisms.
  - Non-native organisms introduced into a new area may outcompete, overeat, and/or replace native organisms, resulting in significant environmental changes.
  - An ecological niche is the role that an organism plays in its environment. An organism's niche includes the resources it uses from the environment and how it acquires and uses those resources.
  - No two species can occupy the same niche at the same time (competitive exclusion principle). Competition between two species sometimes leads to increased niche specialization (resource partitioning), thereby permitting coexistence of multiple species.
  - An adaptation is a physical or behavioral trait of an individual that enhances its chances of surviving and reproducing in an environment. The development of an adaptation does not occur within the lifetime of an organism, but only within populations (and across generations).
  - Individuals of a species or population have variation in their traits. Natural selection refers to the selection by the environment (selective pressure) of those traits that promote survival and reproduction better than others. (Natural selection acting on heritable traits results in the survival of organisms that are more suited to a particular environment.)

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).

The example items below are not included in the AIM assessment, but are shown here to illustrate item features. These example items may be flawed and are not intended to be used in any assessments.

Knowledge of science content

All of the AIM 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 "Level 1" item is shown in Figure 3 (correct answer is B).

Level 1 Item

A teacher poses the following question to her students.

"Are decomposers important to other organisms?"

Which student response is most accurate?

A. Yes, because decomposers are the primary food source for all other organisms in an ecosystem.
B. Yes, because decomposers break down waste, making nutrients available to other organisms.
C. No, because decomposers are not food for other organisms.
D. No, because decomposers interact only with dead things, not with living things.

Figure 3

This item illustrates some features common to all AIM 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, we wanted teachers to 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 D).

Level 2 Item

In a lesson on organisms, a student is placing pictures of different organisms into piles labeled Producer, Consumer, Scavenger, and Decomposer. He comes across a picture of a hyena eating a dead gazelle that had been killed by a lion. The student thinks that the hyena belongs

in both the Scavenger and Consumer piles.

Which of the following is the best assessment of this student's understanding about organisms?

A. The student does not understand that scavengers eat dead organisms.
B. The student does not understand that consumers get their food by eating other organisms.
C. The student understands that some animals eat both plants and other animals.
D. The student understands that scavengers are a type of consumer.

Figure 4

Certainly a teacher must understand the science content in order to select the correct answer choice for Level 2 items. However, additional analysis of the question is required because more than one of the choices includes a correct science statement, unlike the Level 1 item in Figure 3. In Figure 4, the statements in choices A, B, and C are correct in terms of the science, but only D applies to what the students 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 science context in order to determine which answer choice is correct.

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 B).

Level 3 Item

In a lesson on producers and consumers, a student states:

"Consumers eat plants and animals, but producers don't need food."

If most of the class agrees with this statement, what should the teacher do next to further the students' understanding of producers and consumers?

A. Have students plant seeds in cups and watch them over a period of weeks.
B. Explain how plants make their own food.
C. Lead a discussion about students' pets and what they feed them.
D. Have students read about the special role of decomposers.

Figure 5

Level 3 items have the highest cognitive load; teachers must evaluate the science content, the student's thinking in relation to the science content, and then evaluate each instructional choice. As with Level 2 items, more than one answer choice is consistent with a correct interpretation of the science content, but only one has a correct 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.

Item Development

HRI staff drafted items individually then met to edit them collaboratively. As the pool of items grew, we began recruiting elementary school teachers for telephone cognitive interviews. We

interviewed at least three teachers on each item in the pool using the interview protocol shown in Figure 7. After a round of interviews, HRI staff met to discuss teachers' feedback. If substantive edits were made to an item, we interviewed additional teachers about the revised version. When interviews suggested no further edits were needed, we asked a content expert to review all of the items in the pool for content accuracy.

AIM Teacher Assessment Items
Cognitive Interview Protocol

Prologue Script:

Thank you for agreeing to let us interview you. As we explained in the email, we are developing a test for elementary school science teachers, and we need your help to refine the test questions. I don't expect you to get all of the answers right. 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. If you decide you would like to stop at any point, just say so.

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 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?
  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 teachers?
  6. Do you have any other comments on the item?

Figure 6

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 the science, but not in relation to the student's thinking.

Interviews also suggested 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, particularly when the item requires teachers to evaluate which question should be asked next. When the choices are about actual activities, as in the example in Figure 5, teachers sometimes get bogged down in the details of the choices. For instance, they may rule out a choice that requires particular equipment because they do not have access to such equipment, 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.

Pilot

We selected 40 items to pilot with 348 teachers recruited from mailing lists of elementary grades teachers across the country. The pilot was administered via the Internet. Approximately 20 percent of the sample was comprised of teachers who indicated they had taught the content at the middle school level to ensure that some respondents would be at the upper end of the knowledge spectrum.

Table 2
Characteristics of the Pilot Test Sample (N = 348)

	Percent of Teachers
Grade Level Taught in 2009–10[†]	
Kindergarten	1
1st grade	2
2nd grade	3
3rd grade	25
4th grade	29
5th grade	32
6th grade	10
7th grade	12
8th grade	12
9th grade	1
10th grade	0
11th grade	1
12th grade	0
Taken a college-level introductory biology course	
Yes	86
No	14
Gender	
Female	88
Male	12
Race/Ethnicity[†]	
American Indian or Alaskan Native	1
Asian	1
Black or African American	4
Hispanic or Latino	2
Native Hawaiian or Other Pacific Islander	0
White	92

[†] Percentages may add up to more than 100 as teachers could select multiple categories.

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.

Content Coverage

Using results from the pilot, 27 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. There are fewer sub-ideas in Table 3 than in the content unpacking (see Table 1), as limiting the assessment to a total of 27 items required restricting the coverage of sub-ideas. In some cases a sub-idea may not be represented in the final assessment because it was deemed to be less central than others. In other cases, items associated with the sub-idea did not perform as well as others in the pilot study.

Table 3
Number of Items Addressing Each Sub-Idea

Sub-Ideas:	Number of Items
A. Organisms interact and are interdependent in various ways, including providing food and shelter to one another.	8
B. Organisms can survive only in environments in which their needs are met.	3
C. When the environment changes, some plants and animals survive and reproduce; others die or move to new locations.	3
D. Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or, one organism may scavenge or decompose another.	1
E. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.	3
F. The number of organisms and populations an ecosystem can support depends on the biotic resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition.	4
G. All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organisms or other organisms, whereas others are beneficial.	8

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	Sub-Idea						
		A	**B**	**C**	**D**	**E**	**F**	**G**
1	B	P						
2	B	P						
3	A	P						
4	D	P						
5	C	P						
6	C	P						
7	B		P					
8	A	P						
9	A		P					S
10	D		P					
11	D			P				
12	D			S				P
13	C			S				P
14	A				P			
15	B					P		
16	C					P		
17	B					P		
18	A						P	
19	D						P	
20	B						P	
21	C						P	
22	C							P
23	A							P
24	D							P
25	B							P
26	D	P						
27	A							P
Primary:		8	3	1	1	3	4	7
Secondary:		0	0	2	0	0	0	1
Total:		8	3	3	1	3	4	8

Validity
Three lines of evidence support the argument that the assessment is a valid measure of teachers' knowledge of these populations and ecosystems 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 content expert (individual with a Ph.D. in biology) reviewed the assessment items to ensure content accuracy. Third, factor analysis indicates that all items on the assessment measure a single dominant trait. HRI termed this trait "content knowledge for teaching about populations and ecosystems."

Reliability
Both classical test and item response theory (IRT) analyses were conducted on the pilot data and those results were used to select items for the final assessment. These analyses were repeated using data from the pilot combined with data from the final assessment. The final assessment has an IRT reliability of 0.83; reliabilities above 0.60 are generally considered acceptable for making judgments about groups (higher reliabilities are required for making high-stakes decisions about individuals.

Speededness
The pilot was not a timed administration. As such, there is no information about speededness.

Using the Assessment

The AIM Populations and Ecosystems Teacher Assessment is available at no cost through an online process to those who agree to the terms of use (see the Appendix). To complete the terms of use agreement, visit http://www.horizon-research.com/aim/instruments/.

Appropriate Use
The AIM Populations and Ecosystems Teacher Assessment yield a score for each individual. However, the assessment is not valid for making judgments about individuals based on those scores. For instance, evaluating teacher performance 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
- Researching the relationship between teacher knowledge and other variables (e.g., student learning).

Amount of Time Required to Complete the Assessment
As described above, the pilot test was administered on-line and was not timed. Although there is no evidence of speededness, it is recommended that at least 30 minutes be allowed for completing the assessment.

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 scale score.

Table 5
Assessment Score Conversions

Raw Score	Scale Score
0	0
1	13
2	20
3	25
4	29
5	32
6	35
7	37
8	40
9	42
10	44
11	46
12	48
13	49
14	51
15	53
16†	55†
17	57
18	59
19	61
20	63
21	66
22	68
23	71
24	75
25	80
26	88
27	100

† Mean value

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

National Assessment Governing Board, U.S. Department of Education. (2008) *Science framework for the 2009 national assessment of educational progress*. Washington, DC: U.S. Government Printing Office.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Appendix
Terms of Use Agreement
Populations and Ecosystems Elementary School Teacher Assessment

By using the AIM Populations and Ecosystems Teacher Assessment 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 Populations and Ecosystems 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; and
- Offer teachers compensation for time spent outside of the regular school day completing the assessment.

Test Security

The AIM Populations and Ecosystems 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 AIM Assessments

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

The assessment was developed by the Assessing the Impact of the MSPs: K–8 Science (AIM) project at Horizon Research, Inc., funded by the National Science Foundation under grant number DUE-0928177. Any opinions, findings, and conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation or Horizon Research, Inc.

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: _____