ATLAST Flow of Matter and Energy Student Assessment
User Manual

1. Overview

The ATLAST Flow of matter and Energy Student Assessment is a 30-item multiple-choice assessment for middle grades students. The assessment measures understanding of the following set of concepts:

> *"Food provides molecules that serve as fuel and building materials for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food [sugars] can be used immediately for fuel or materials, or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms."* (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 Flow of Matter and Energy 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. EHR-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.

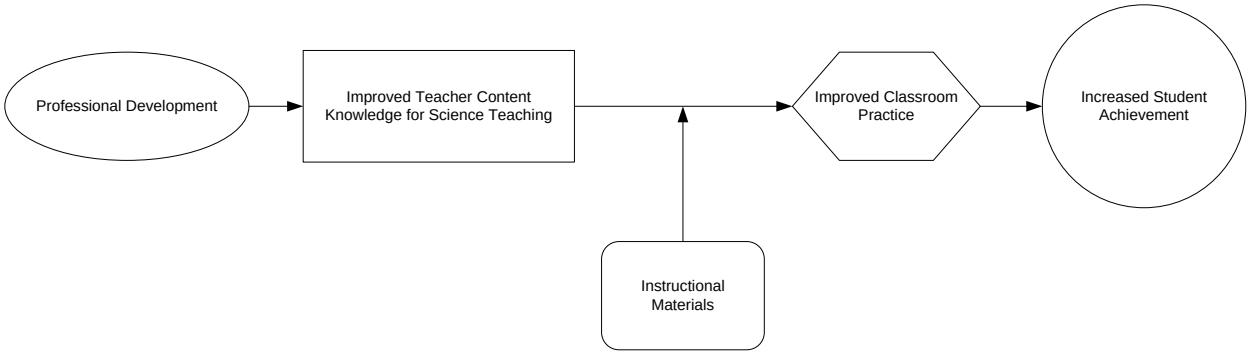

Figure 1
ATLAST Theory of Action

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 Flow of Matter and Energy 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.

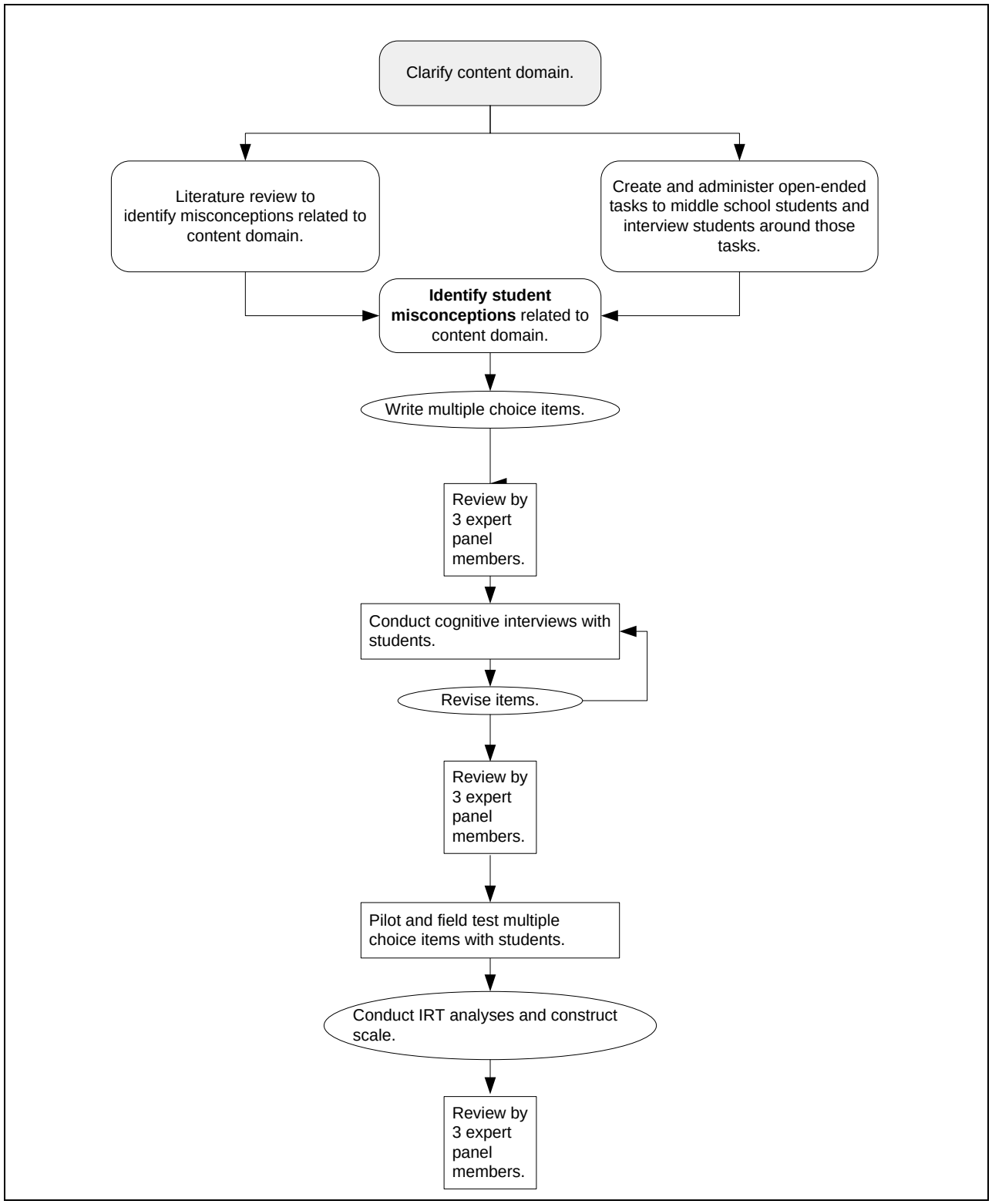

Figure 2
ATLAST Assessment Development Process

3.1 Clarifying the Content Domain

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

> "*Food provides molecules that serve as fuel and building materials for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food [sugars] can be used immediately for fuel or materials, or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.*" (American Association for the Advancement of Science/Project 2061, 1993).

HRI specified the domain by "unpacking" this idea into 11 "sub-ideas," which were reviewed by four biologists/biology 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 seven sub-ideas.

Table 1
Flow of Matter and Energy Content Domain

Targeted Ideas: Food provides molecules that serve as fuel and building materials for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food [sugars] can be used immediately for fuel or materials, or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms

Sub-ideas:

A. Food serves as both fuel (energy source) and building materials for an organism. Sugars are an example of food for both plants and animals, but water, carbon dioxide, and oxygen are not..
B. Using light energy, plants make their own food - in the form of sugars - from carbon dioxide (in the air) and water. Nothing else is required for this process. Oxygen is released as a result.
C. Plants transform light energy into chemical energy in sugars made by the plants.
D. Humans and other animals acquire food by consuming plants or other animals that have consumed plants. Animals break down this food into simpler substances (including sugars). **
E. Organisms (including both plants and animals) grow by breaking down food (including sugars made by plants and sugars ingested by animals) into simpler substances which they reassemble into other substances that become part of new or replacement body structures.
F. Organisms (including both plants and animals) break down energy-rich food (such as sugars), using oxygen, into simpler substances with less energy (such as carbon dioxide and water), releasing energy in the process. This process does not require light. Some of this energy from food is used for growth and other body functions, and some is released as heat.
G. If not used immediately as fuel or building material, food can be stored for later use by plants and animals. In animals, but not in plants, food can also be eliminated from the body as waste.
H. **Respiration** is the continual process by which an organism uses oxygen and sugars to release energy: $6O_2 + C_6H_{12}O_6 \rightarrow 6H_2O + 6CO_2$ + energy. *
I. **Photosynthesis** is the process by which a plant uses the energy from light to make sugars from carbon dioxide and water: Light energy + $6H_2O + 6CO_2 \rightarrow 6O_2 + C_6H_{12}O_6$
Note: The oxygen that is released comes from the water, not the CO_2. Energy comes from light, not heat of the Sun. *
J. Some energy is lost to the system as heat between each trophic level, so only a portion of the energy is passed from one trophic level to the next. This continuous loss of energy to the system as heat means that an outside source of energy (usually the Sun) is required to maintain the flow of energy in ecosystems. *
K. Decomposers transform dead organisms into simpler substances that can be used by plants and other organisms. This release of nutrients back into the environment is necessary to complete the cycle of matter. *

* These sub-ideas are for teacher only; they are not assessed at the student level
** This sub-idea is integral to the benchmark, but is covered in grades 3-5. No items were written around this sub-idea...

3.2 Item Development

Development of the multiple-choice items began with identifying student misconceptions in the area of Flow of Matter and Energy in Living Systems. 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 Flow of Matter & Energy. Thus in addition to gleaning student misconceptions from the literature, 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**
Food serves as both fuel (energy source) and building materials for an organism. Sugars are an example of food for both plants and animals, but water, carbon dioxide, and oxygen are not.	• Food is a requirement for growth, but the resulting matter generated by growth comes from another source. • Plants (or other living organisms) take in and use some substances, and produce others. These are separate events – substances taken in are not raw materials for the products. • Food is anything that goes into an organism – CO_2, water, sunlight, oxygen, etc. • Food is what is needed to keep plants and animals alive. • Food is anything edible. • Food is energy. • Food cannot be liquid. • Food must taste good/to be "healthy"/not make you sick. • Sugars are bad for you.

Figure 3: A Flow of Matter and Energy Sub-idea with Associated Research on Student Thinking

After relevant student misconceptions had been identified, 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 flow of matter and energy in living systems, 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 re-read 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 s/he 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.

Are sugars food for plants?

A. *Yes*, because sugars are energy.
B. *Yes*, because sugars provide energy and matter for plant growth.
C. *No*, because plants don't take in sugars.
D. *No*, because sugars are not necessary for plant growth.

Figure 5
Flow of Matter and Energy Item

This item illustrates some features common to all ATLAST student 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 48 flow of matter and energy student items were included in a pilot test. Due to the large number of items, the pilot was administered in two forms of 33 items with 18 linking items. Approximately 4,000 middle school students across the nation responded. Review of the responses and analysis of the data suggested that some items should 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 33 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 = 4,641)

	Percent
Grade Level	
6th	31
7th	40
8th	28
Gender	
Female	50
Male	50
Race/Ethnicity	
American Indian or Alaskan Native	5
Asian	4
Black or African American	14
Hispanic or Latino	22
Native Hawaiian or Other Pacific Islander	3
White	64
English Language Learner	12

3. 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.

3.1 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. Food serves as both fuel (energy source) and building materials for an organism. Sugars are an example of food for both plants and animals, but water, carbon dioxide, and oxygen are not.	5
B. Using light energy, plants make their own food - in the form of sugars - from carbon dioxide (in the air) and water. Nothing else is required for this process. Oxygen is released as a result.	7
C. Plants transform light energy into chemical energy in sugars made by the plants.	6
D. Humans and other animals acquire food by consuming plants or other animals that have consumed plants. Animals break down this food into simpler substances (including sugars).	0
E. Organisms (including both plants and animals) grow by breaking down food (including sugars made by plants and sugars ingested by animals) into simpler substances which they reassemble into other substances that become part of new or replacement body structures.	6
F. Organisms (including both plants and animals) break down energy-rich food (such as sugars), using oxygen, into simpler substances with less energy (such as carbon dioxide and water), releasing energy in the process. This process does not require light. Some of this energy from food is used for growth and other body functions, and some is released as heat.	2
G. If not used immediately as fuel or building material, food can be stored for later use by plants and animals. In animals, but not in plants, food can also be eliminated from the body as waste	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*	*B*	*C*	*D*	*E*	*F*	*G*
1	A	P						
2	A		P					
3	B						P	
4	A			P				
5	A							P
6	A			P				
7	A					P		
8	C		P					
9	C						P	
10	D		P			s		
11	C							P
12	B			P				
13	B	P						
14	D							P
15	B			P				
16	C							P
17	B		s			P		
18	D	P						
19	B			P				
20	D							P
21	D		P					
22	C	P						
23	B					P		
24	A							P
25	B		P					
26	C		P					
27	C							P
28	A	P				s		
29	C			P				
30	C					P		
Primary:		5	6	6	0	4	2	7
Secondary:		0	1	0	0	2	0	0
Total:		5	7	6	0	6	2	7

3.2 Validity
Three lines of evidence support the argument that the assessment is a valid measure of students' knowledge of flow of matter and energy 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 biology) 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 the flow of matter and energy in living systems."

3.3 Reliability
The assessment has an internal reliability of 0.78.

3.4 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; that is, the proportion of missing answers among the final items on the assessment than there was for earlier items, suggesting that students did not run out of time.

4. Using the Assessment

The ATLAST Flow of Matter and Energy 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.

4.1 Appropriate Use
The ATLAST Flow of Matter and Energy 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.

4.2 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.

4.3 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

Flow of Matter and Energy Student Assessment			Raw Scores	
Raw Score	Scaled Score		Mean	SD
0	5		12.78	5.17
1	7			
2	11			
3	13			
4	14			
5	18			
6	20			
7	25			
8	27			
9	30			
10	33			
11	36			
12	39			
13	**42**			
14	46			
15	49			
16	52			
17	55			
18	59			
19	65			
20	68			
21	71			
22	73			
23	78			
24	80			
25	84			
26	87			
27	90			
28	93			
29	97			
30	100			

References

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy* (p. 418). New York: Oxford University Press.

Carlsen, W. (1999). Domains of teacher knowledge. In J. Gess-Newsome & N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 133-144). Norwell, MA: Kluwer Academic Publishers.

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Veal, W. R., & MaKinster, J. G. (1999). Pedagogical Content Knowledge Taxonomies. *Electronic Journal of Science Education*, *3*(4).

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of research in education*, 173-209.

Terms of Use Agreement
Flow of Matter and Energy Student Assessment

By using the ATLAST Flow of Matter and Energy 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 Flow of Matter and Energy 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 day administering the assessment.

Test Security

The ATLAST Flow of Matter and Energy 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: _____