SCIENCE

NAEP

GRADE	SCORES		TOTAL SCORE
A-	Content and Rigor	7/7	9/10
	Clarity and Specificity	2/3	

Overview

The NAEP *Science Framework* for science is an extended statement of science learning expectations at grades four, eight, and twelve. The NAEP assessment is based on the science content, skills, and testing procedures outlined in the *Framework*. Sample questions show how learning expectations discussed in the *Framework* are actualized in the assessment.

Although the *Framework's* design and organization are complex and in a few places difficult to understand, in general the document works well, providing a useful epitome of K-12 science knowledge and related skills.

There are two main issues to be addressed in evaluating this *Framework*. One is length—the number of content expectations that it includes is substantial, even though limited to three grade levels. The second is purpose: How may we evaluate this *Framework*, which is conceived as a design for testing, as a set of standards that can guide curriculum making? Early in its 155 pages, the *Framework* makes this important distinction between content and curriculum:

> **Key *principles as well as facts, concepts, laws, and theories* that describe regularities in the natural world are presented…as a series of *content statements* to be assessed at grades 4, 8, and 12…[T]hese statements comprise the NAEP science content. *They define only what is to be assessed by NAEP and are not intended to serve as a science curriculum framework.* (emphasis added)**

The writers are to be congratulated for having taken the trouble thus to define "content" as used by them. Yet although the *Framework* is not intended as a comprehensive set of standards for K-12 science, it clearly does *imply* such a set. In fact, it is unlikely that state education officials, district administrators, and teachers will ignore its plentiful science content and proposed achievement levels, particularly in light of the strong influence that NAEP and its assessment results carry in American primary and secondary education. Thus, we treat the NAEP *Science Framework* here as a set of expectations for K-12 science knowledge—a.k.a. science content standards.

Organization of the Framework

NAEP sidesteps enduring debates over how to define scientific relationships among themes, principles, content, practices, scientific reasoning, inquiry, and so forth by

Document(s) Reviewed

- *Science Framework for the 2009 National Assessment of Educational Progress*. 2009. Accessed from: http://www.nagb.org/publications/frameworks/science-09.pdf
- *NAEP Science Sample Questions: Grade 4*. 2009. Accessed from: http://nces.ed.gov/nationsreportcard/pdf/demo_booklet/09SQ-O-G04-MRS.pdf
- *NAEP Science Sample Questions: Grade 8*. 2009. Accessed from: http://nces.ed.gov/nationsreportcard/pdf/demo_booklet/09SQ-G08-MRS.pdf
- *NAEP Science Sample Questions: Grade 12*. 2009. Accessed from: http://nces.ed.gov/nationsreportcard/pdf/demo_booklet/09SQ-G12-MRS.pdf

Figure 1. Crossing content and practices to generate performance expectations

		Science Content		
		Physical Science Content Statements	**Life Science Content Statements**	**Earth and Space Sciences Content Statements**
Science Practices	**Identifying Science Principles**	**Performance Expectations**	**Performance Expectations**	**Performance Expectations**
	Using Science Principles	**Performance Expectations**	**Performance Expectations**	**Performance Expectations**
	Using Scientific Inquiry	**Performance Expectations**	**Performance Expectations**	**Performance Expectations**
	Using Technological Design	**Performance Expectations**	**Performance Expectations**	**Performance Expectations**

dividing science knowledge into just two broad categories: principles and practices. The various principles comprise what is usually called science content: facts, concepts, theories, and laws. They are organized into the now-familiar content areas: physical, life, and earth and space sciences.

Next, NAEP identifies four science practices: identifying science principles, using science principles, using scientific inquiry, and using technological design.

Finally, the *Framework* designers assemble all three areas of general content (principles and their expansions) and all four general areas of practice into a matrix. Each resulting cell of this matrix is a potentially large set of performance expectations (see Figure 1). Thus for every general content area, there are four possible (and testable) practices corresponding to the -*ing* actions listed: 1) recognizing, naming, or describing the content; 2) employing the content correctly in one of its contexts; 3) showing skills needed to use that content in answering a scientific question, and 4) applying the content in a design or engineering problem.

Organization of Content Topics

Within the three main content domains (physical, life, and earth and space), how many standards do K-12 students really need to meet? In science education, at present, this is a vexed question. Some say "very few." Others say "enough to display, at least, the *range* of modern science." Still others would answer "a whole lot." NAEP settles somewhere in the middle by expanding its three content areas into eighteen foundational statements: six on physical science, five on life science, and seven on earth and space science. These are then further specified by various detailed explanations encompassing most of the basics at each assessed grade level (four, eight, and twelve), but increasing in number, sophistication, and detail from fourth grade through twelfth grade.

The physical science content area illustrates this complex structure. It is divided into six basic principles: properties of matter, changes in matter, forms of energy, energy transfer and conservation, motion at the macroscopic level, and forces affecting motion. These six principles are represented by fifteen actual content statements in fourth grade, by sixteen statements in eighth grade, and by twenty-three statements in twelfth grade. Therefore, all assessable physical science is represented in this *Framework* by fifty-four short statements of science content.

Moreover, these content statements are amplified at each grade. For example: One of the six principles of physical science is "changes in matter." In fourth grade, this principle is represented by one explicit content standard—that cooling and heating can convert matter from one recognizable state (solid, liquid, or gas) to another. In eighth grade, "changes in matter" expands to two representations, one on the molecular organization of matter and the other on chemical reactions and the conservation of mass in the course of reaction. And by twelfth grade, this principle expands to three (carefully crafted) statements, one on the energetics of state change, a second on atomic structure and electrons in atoms, and a third on chemical bonds and reactions.

In addition to the fifty-four content statements for physical science, there are thirty-two for life science and thirty-nine for earth and space science—a total of 125 explicit content statements. Since all the assessable content of K-12 science is supposed to be covered, that is not an unreasonable number.[1]

Content and Rigor

Physical Science

Content statements for fourth-grade physical science are comprehensive and emphasize properties, states, and transformations of matter. They address adequately the basics of energy and motion in grade-appropriate terms. Content statements for eighth-grade physical science—concerned with physical and chemical change—are more specific and comprehensive than are our own criteria (see Appendix A). For twelfth grade, content is strong except for light treatment of some important advanced topics of twelfth-grade chemistry (reaction mechanisms, acid-base chemistry, chemical bonds in important classes of macromolecules). Overall, the physical science content presented covers the necessary ground with neither critical omissions nor trivialities.

Earth and Space Science

The earth and space science content is well chosen. Content and sequencing concerning Earth's internal structure and plate tectonics—including the key geological evidence from seafloor spreading—are analytical and sufficiently comprehensive. For the principle "earth in space and time," the single fourth-grade expectation appropriately concerns the distinction between slow and catastrophic change. Fossils appear in eighth grade, as do mountain building and erosion. Twelfth-grade expectations expand to include, among other topics, the scale and magnitudes of geologic time. Perfect science standards would give more attention to the earth's age and to stellar evolution (as exemplified in the Hertzsprung-Russell diagram). The *Framework* gives weather and climate unusual prominence, but at the expense of astronomy and cosmology. That said, the development of scientific ideas is generally appropriate throughout the grades, and the few omissions are compensated for by careful presentation of the included content.

Life Science

Life science coverage is broad and reasonably inclusive. Basic themes—such as the mechanisms of heredity—are represented (as they should be) at all three grade levels. But "evolution and diversity," central to modern biology, does not appear until eighth grade—and some even of its simplest elements not until twelfth grade. Even then, there is no mention of the now-indispensable molecular and population genetics relevant to evolution. Somewhat disproportionate attention is paid to ecology and ecosystems (here under the thematic head of "interdependence"), and that comes at the expense—inter alia—of physiology, control systems, and developmental biology. Basic cell biology, on the other hand, is very well covered and is sequenced thoughtfully by grade.

The *Framework's* principles and detailed content statements cover virtually all the expectations spelled out in our review criteria and introduce no significant peripheral matter. A full-credit score of seven out of seven for content and rigor is justified. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

This *Framework* document concedes—as it must—that distinctions among its four basic practices are anything but sharp. They are nevertheless convenient for communicating skill expectations and for representing the underlying standards that must guide writers of test questions. The authors are evidently comfortable with the residual ambiguities, perhaps judging that they do not damage the implied standards. They make possible, presumably, the construction of fair and comprehensive tests, which is of course what the *Framework* is about. Nevertheless, while the total number of principles is appropriate, the potentially dense intersections of them and the practices (that is, the total number of principles as expanded grade by grade, multiplied by the four broad and not sharply distinguishable practices) make it difficult for a reader to comprehend a bounded set of expectations. Thus clarity is to some extent compromised by complexity; as such, the *Framework* is awarded a score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)

[1] The *Framework* reports that content selection was guided primarily by two national sources: the *Benchmarks for Science Literacy* of the American Association for the Advancement of Science (1993) and the *National Science Education Standards* of the National Research Council (1996), plus follow-up documents. The authors note, however, that those documents do not limit or prioritize content in the form of assessable units. (In fact they are often concerned with history, philosophy, and sociology of science.) The NAEP *Science Framework* concerns itself with "science" as commonly understood. And its tabulated content is justified and supported by clarifications and discussions of "crosscutting"—content relevant to more than one of the three science domains.