SCIENCE

Connecticut

GRADE	SCORES		TOTAL SCORE
C	Content and Rigor	4/7	6/10
	Clarity and Specificity	2/3	

REPORT CARD

Content & Rigor	**4.0**
Scientific Inquiry & Methodology	2
Physical Science	5
Physics	4
Chemistry	4
Earth & Space Science	5
Life Science	4
Clarity & Specificity	**1.8**

Average numerical evaluations

Overview

The Connecticut science standards are generally well written, with but a few scientific errors or badly phrased statements. Unfortunately, a significant amount of important material is missing, preventing the Constitution State from earning top marks across the board.

Organization of the Standards

The Connecticut science standards include three documents: the main *Curriculum Framework* document, a *Grade-Level Expectations* document, and a *Matrix of K-10 Content Development*. Within the *Framework*, Connecticut's science standards are organized around eleven conceptual themes, such as inquiry, forces and motion, the changing Earth, and science and technology in society. For each theme, the state provides several grade-specific content standards and "expected performances" that illustrate what will be assessed on the state tests.

The high school standards are organized similarly, with two exceptions. First, the conceptual themes for ninth and tenth grades are further subdivided into five strands. Strands I, II, and III speak to the physical sciences, and strands IV and V to the life sciences. Second, the content standards for eleventh and twelfth grades—as well as those for the high school physics, chemistry, earth science, and biology courses—are articulated through the state's "enrichment curriculum" at the end of the document.

In addition, the state offers a grade-level expectations document for grades preK-8 to support the *Framework*. This document repeats all the material that is in the curriculum framework, and adds grade-level expectations that further clarify each content standard.

Finally, the state provides the *Matrix of K-12 Content Development*, which briefly (in six pages) describes the "progressive development of conceptual themes" in scientific inquiry, earth science, life science, and physical science for each grade, preK-8, and then for high school.

All of the science standards documents say much the same thing, although in quite different ways—increasing the risk that the material will confuse readers.

Document(s) Reviewed[1]

- *Connecticut Core Science Curriculum Framework*. 2005. Accessed from: http://www.sde.ct.gov/sde/lib/sde/word_docs/curriculum/science/framework/sciencecoreframework2005v2.doc
- *Connecticut PreK-8 Science Curriculum Standards Including Grade-Level Expectations*. 2009. Accessed from: http://www.groton.k12.ct.us/cms/lib2/CT01001200/Centricity/Domain/47/PK8_sciencecurriculumstandards2009.pdf
- *Connecticut Core Science Curriculum Framework: Matrix of K-10 Concept Development*. 2005. Accessed from: http://www.sde.ct.gov/sde/lib/sde/word_docs/curriculum/science/framework/matrix2005.doc

[1] In 2011, Connecticut released an updated version of its preK-8 grade-level expectations (dated 2010). Following this review of the 2009 document, we present a brief comparison review of the 2010 version.

Content and Rigor

The Connecticut standards are generally strong and cover most of the important topics in science with adequate depth and rigor. The one notable exception is the scientific inquiry and methodology standards, which are overly brief and provide little guidance about what knowledge and skills students should learn.

Scientific Inquiry and Methodology

As mentioned above, the scientific inquiry and methodology standards are the weakest of the Connecticut standards. The expectations emphasize acquisition of three (cognitive) skills—scientific inquiry, scientific literacy, and scientific numeracy—but the associated standards comprise a mere four pages. So, for example, students are expected to "use data to construct reasonable explanations" in third through fifth grades, but no guidance is provided as to what constitutes a "reasonable" explanation at that level of schooling. In the same vein, students in higher grades are asked to "design and conduct appropriate types of scientific investigations."

At other points, expectations for student performance in this realm seem far too ambitious. For example, the core curriculum for sixth through eighth grades explains:

> **Scientific literacy also includes the ability to search for and assess the relevance and credibility of scientific information found in various print and electronic media. (grades 6-8)**

The corresponding "expected performance" column asks students to "read, interpret, and examine the credibility of scientific claims in different sources of information." Such ability is anything but common, even among professionals. For school science, aspiration is one thing; practical expectation, the most important element of a learning standard, is quite another.

Note, too, that—perhaps because of their overall brevity—Connecticut's inquiry and methodology standards make no mention whatsoever of the history of science.

Physical Science

Much of the content included in the Connecticut standards is covered with adequate depth and rigor. In addition, the grade-level expectations often helpfully build upon the standards provided in the curriculum framework. For instance, a second-grade standard explains that "solids tend to maintain their own shapes, while liquids tend to assume the shapes of their containers, and gases fill their containers fully." The related expectation asks students to:

> **Compare and contrast the properties that distinguish solids, liquids, and gases.**
>
> **Classify objects and materials according to their state of matter.**
>
> **Measure and compare the sizes of different solids.**
>
> **Measure and compare the volume of a liquid poured into different containers.**
>
> **Design a fair test to compare the flow rates of different liquids and granular solids. (grade 2)**

Similarly, in fourth grade, students are introduced to electromagnetism with a fine series of standards, some of which are:

> **Predict whether diagrammed circuit configurations will light a bulb.**
>
> **Develop a method for testing conductivity, and analyze data to generalize about which materials are good electrical conductors and which are good insulators.**
>
> **Observe magnetic effects associated with electricity and investigate factors that affect the strength of an electromagnet. (grade 4)**

Other times, however, the standards introduce errors or are too vague to guide rigorous curriculum and instruction. For example, fifth-grade students are asked to "explain that all visible objects are reflecting some light to the human eye." Of course, this is not necessarily true since there *are* self-luminous objects.

In eighth grade, students are asked to:

> **Assess in writing the relationship between an object's mass and its inertia when at rest and in motion. (grade 8)**

What the student is actually expected to do and say here is a mystery.

High School Physics

Connecticut's high school physics standards are generally demanding, though the presentation is confusing and disorganized. This is unsurprising, considering that all high school physics content is compressed into fewer than two pages of standards.

That said, simple mathematical expressions are used whenever appropriate. For example, Newton's laws of motion are dealt with in a systematic and straightforward fashion:

> **When forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest.**
>
> **The law $F = ma$ is used to solve motion problems that involve constant forces.**
>
> **When one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction.**
>
> **Applying a force to an object perpendicular to the direction of its motion causes the object to change direction. (high school physics)**

And though it is brief, the coverage of heat and thermodynamics is among the best we have seen in terms of clarity and completeness:

> **Heat flow and work are two forms of energy transfer between systems.**
>
> **The work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature.**
>
> **The internal energy of an object includes the energy of random motion of the object's atoms and molecules. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object.**
>
> **Most processes tend to decrease the order of a system over time, so that energy levels eventually are distributed more uniformly. (high school physics)**

The coverage of energy and momentum, waves, and electromagnetism is presented in a similarly brief but cogent fashion. Missing, however, is pretty much all of modern physics.

High School Chemistry

The Connecticut chemistry standards are generally succinct and clearly written, touching upon a good deal of essential content. Some of it, including rates of reaction and chemical bonding, is covered well, as in the following:

> **Salt crystals, such as NaCl, are repeating patterns of positive and negative ions held together by electrostatic attraction. (high school chemistry)**

Unfortunately, the standards are not always worded as specifically or completely as this example, and important related material is often missing entirely. For example, one standard gives the definition of equilibrium, but mentions nothing else, not even Le Châtelier's principle.

A set of standards deals with moles, but stoichiometry of both chemical formulas and balanced equations are omitted. Another standard declares that "electronegativity and ionization energy are related to bond formation," but neglects to include *how* they are related.

Even more troubling, several major topics are missing entirely. These include solutions, oxidation/reduction reactions, acid/base chemistry, gases, and spectra/electron transition connections.

Earth and Space Science

The coverage of earth and space science is quite broad, but with a mix of rigorous and inadequate standards. On the high side are some beautifully written standards, such as this one:

> **The properties of rocks and minerals can be explained based on the physical and chemical conditions in which they were formed, including plate tectonic processes. (high school earth science)**

Still, a few topics are weak or completely missing. Fossils are never mentioned in the earth science material (although there is a brief mention in biology), nor are methods of absolute and relative dating of rocks.

Other essential topics are present, such as plate tectonics, earthquakes, and volcanoes, but the coverage is spotty. And sometimes a standard is too vague to be useful. Sixth graders, for example, are asked to "observe, analyze and record the unique physical and chemical properties of water." This statement is both unclear (water has many special properties; to which is Connecticut referring?) and too advanced for the grade level (the underlying theory is more appropriate for high school).

The rock cycle is not mentioned by name, and the details of rock formation that are implied are probably too advanced for the level at which they are presented. For example:

> **Observe and analyze rock properties (e.g., crystal size or layers) to infer the conditions under which the rock was formed. (grade 3)**

Extra-solar-system astronomy and cosmology are treated at the high school level clearly and logically, but too briefly. The standards ask for evidence for important theories such as the Big Bang, but said theories are not described.

Life Science

From Kindergarten through eighth grade, Connecticut's life science standards are adequate, but a few key topics are absent. For instance, there isn't an appropriate early introduction to Mendelian genetics and the existence, nature, and action of genes.

Curious inconsistencies also appear. For example, in fifth grade, sophisticated concepts and assignments are put forward, like "explore factors that affect human reaction time" and "describe the properties of different materials and the structures in the human eye that enable humans to perceive color." Yet students will have been taught nothing about cells, neurons, membranes, channels, receptors, and other necessary concepts and thus will lack the background to meet any such requirement. They don't even hear about cells until seventh grade.

The high school biology course is also superficial, with vague coverage of meiosis, cell structure, DNA, and most other topics.

Despite a good, early introduction to the idea of adaptation, the standards through eighth grade ignore other key ideas of evolutionary biology. At the high school level, evolution is again treated oddly. We're told about natural selection, genetic drift, and geographic isolation, but there's nothing about common ancestry, the more than three billion years of life's evolution, and so on. The unit ends with, "Several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another" (high school biology). But we're not told how long ago that was.

Taken together, these inadequacies push Connecticut's average score down to a four out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

Connecticut's science standards are generally clear and well written, and for the most part, the content is logically organized and presented. As noted above, the standards introduce sufficient science content (with a few exceptions), and the grade-level expectations usefully specify how student mastery should be assessed and demonstrated.

There are exceptions. Some standards are vague, speaking around the necessary content instead of addressing it head-on. In the following eighth-grade standard, for example, it would be better to ask students to discuss the inverse-square nature of the gravitational force, rather than:

> **Relate the strength of gravitational force between two objects to their mass and the distance between the centers of the two objects and provide examples. (grade 8)**

Likewise, other standards speak around mathematical expressions, leaving the reader to parse through convoluted text.

> **Express mathematically how the mass of an object and the force acting on it affect its acceleration. (grade 8)**

Why not demystify this and ask students simply to understand the common expression, $F = ma$?

Overall, the Constitution State provides students and teachers with a well outlined and logically ordered set of standards, but the potential for excellence exists. The vagueness and unnecessarily complex text pushes Connecticut down to a score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)

Comparison Review of Connecticut's 2009 and Updated 2010 Grade-level Expectations

Documents Compared

Connecticut Prekindergarten–Grade 8 Science Curriculum Standards Including Grade-Level Expectations. March 2009. Accessed from: http://www.groton.k12.ct.us/cms/lib2/CT01001200/Centricity/Domain/47/PK8_sciencecurriculumstandards2009.pdf

Prekindergarten–Grade 8 Curriculum Standards and Assessment Expectations: Science. 2010. Accessed from: http://www.sde.ct.gov/sde/lib/sde/pdf/curriculum/science/pk8_science_curriculumstandards2011.pdf

Overview

When our expert reviewers began analyzing the standards in late 2010, the Connecticut science standards were comprised of three documents: a 2005 *Curriculum Framework*, a 2005 *K-10 Content Matrix*, and a 2009 *Grade-Level Expectations* document. Since then, however, the state has adopted an updated 2010 *Grade-Level Expectations* document. While our reviewers evaluated the 2009 *Grade-Level Expectations* document in their formal review, in order to fairly assess the most recent Connecticut standards, we have included a comparison review of the updated 2010 document below.

Comparison: 2009 to 2010 Grade-Level Expectations

Though both the 2009 and the 2010 versions of the Connecticut preK-8 grade-level expectations generally cover the same material (and are, in fact, both based on the 2005 framework document reviewed above), the writers have added a section of "grade-level concepts" in the 2010 version. These concepts are an expansion of the grade-level expectations, explaining what students should "understand" (in addition to the expectations, which explain what students "should be able to" do).

Overall, the addition of these grade-level concepts is a mixed bag. In some instances, they provide otherwise-lacking depth and clarity to the standards. In the "heredity and evolution" section, for example, the 2010 document provides a solid explanation of heredity that was absent from the 2009 version. Likewise, units are added to one of the seventh-grade physical science standards, supplying helpful detail: "Work (measured in joules) is calculated by multiplying the force (measured in newtons) times the distance (measured in meters)..."

Further, the terse earth and space science standard, "Investigate and determine how glaciers form and affect the earth's surface as they change over time," gets expanded to the much more thorough:

> **Glaciers form in areas where annual snowfall is greater than the seasonal melt, resulting in a gradual build-up of snow and ice from one season to the next.**
>
> **Glaciers increase and decrease in size over long periods of time, depending on variations in Earth's climate.**
>
> **Glaciers move slowly, spreading outward across a region or moving down a slope.**
>
> **Moving glaciers reshape the land beneath them by scraping, carving, transporting and depositing soil and rock.**
>
> **Glacial landforms have identifiable shapes. Connecticut's landscape provides many examples of glacial movement and deposition. (grade 7)**

In other places, however, the "concepts" oversimplify standards or, worse, introduce errors, as in the following earth and space science standard:

> **All rocks are made of materials called minerals that have properties that may... (grade 3)**

In fact, all rocks are *not* made of minerals. And,

> **Earth's crust is broken into different "tectonic plates" that float on molten rock and move very slowly. Continental drift is driven by convection currents in the hot liquid mantle beneath the crust. (grade 7)**

This is a jarring misstep: Plates are made of lithosphere, not just crust. And lithosphere consists of the entire crust plus a little of the *solid* mantle. Almost the entire mantle is solid, not molten, though it does undergo slow convection. This is an important scientific point.

The Bottom Line

The 2010 *Curriculum Standards* admirably expand upon some key concepts that were shallowly presented in the 2009 document. However, they also introduce a number of generalizations and errors into the standards. On the whole, these additions even out; our final grade for Connecticut remains the same.