SCIENCE

Tennessee

GRADE	SCORES		TOTAL SCORE
D	Content and Rigor	**3/7**	4/10
	Clarity and Specificity	**1/3**	

REPORT CARD

Content & Rigor	**3.0**
Scientific Inquiry & Methodology	2
Physical Science	4
Physics	2
Chemistry	4
Earth & Space Science	5
Life Science	1
Clarity & Specificity	**1.3**

Average numerical evaluations

Overview

The Tennessee science standards are clearly written—but their linguistic clarity too often is undermined by statements that are so broad they starve the passages of meaning. To make matters more confusing, Tennessee offers a bewildering array of high school courses. Taken together, these drawbacks make it impossible to infer what a student in the Volunteer State will know (or at least be expected to know) upon graduation.

Organization of the Standards

The Tennessee K-8 science standards are divided into five strands: inquiry, technology and engineering, life science, earth and space science, and physical science. Within each strand, a series of three to five "standards" is articulated. Then, beneath each standard, the state articulates a "conceptual strand" that is meant to define the "big ideas" within the strand that all students should grasp before they graduate from high school, as well as a series of guiding questions that are meant to "sharpen and inform instructional articulation." Finally, grade-level expectations (GLEs) are provided.

In addition, Tennessee provides suggested "checks for understanding," which are suggestions for how teachers can assess each GLE in the classroom, and "state performance indicators," which explain how each standard will be assessed by the state.

At the high school level, the standards are organized similarly, except that expectations are presented by course, rather than by grade, for thirteen different college-prep high school courses, five vocational courses, and five Advanced Placement courses.

Content and Rigor

The Tennessee standards contain islands of strength, but these get lost amid the overwhelming sea of disorder and confusion that more often characterizes the document. Furthermore, every discipline is missing critical content, some of them egregiously so. How this material could serve to build a rigorous K-12 science curriculum is difficult to imagine.

Document(s) Reviewed

- *Tennessee Elementary K-8 Science Standards*. 2007. Accessed from: http://www.tn.gov/education/ci/sci/index.shtml
- *Tennessee Secondary 9-12 Science Standards*. 2008. Accessed from: http://www.tn.gov/education/ci/sci/index.shtml

Scientific Inquiry and Methodology

The guiding question provided by the main inquiry standards asks students, “What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?” And, while answers are given, they are so vague and formulaic that they fail to adduce the content that students would need to learn to conduct inquiry investigations. For example, grade-level expectations for Kindergarten, first, and second grade ask students to “explain the data from an investigation” or to “communicate understanding of simple data,” but what that should look like in any of the three grades is never articulated. Not until high school is the concept of making and testing hypotheses even mentioned.

Coverage of the historical and social aspects of science is perfunctory. History is not presented at all in Kindergarten through eighth grade, and in high school students “trace the historical development of a scientific principle or theory”—to what end, though, remains unstated. Chemistry, biology, and physics at the high school level all include a standard on “embedded technology and engineering,” with the guiding question, “How do science concepts, engineering skills, and applications of technology improve the quality of life?” Historical and ethical aspects of this question are avoided, beyond a vague expectation to “explore the impact of technology on social, political, and economic systems.”

Physical Science

The physical science program is academically weak from Kindergarten through eighth grade. The standards frequently omit critical content and repetition within and between grades. For instance, heat and temperature are never defined, much less differentiated.

Vagueness is a problem throughout. For example, in fourth grade, students must “use appropriate tools to measure and compare the physical properties of various solids and liquids” and “compare the causes and effects of various physical changes in matter.” This sort of hand-waving is of no use to those actually charged with instructing students.

Adding to these problems, the coverage of important topics is severely marred by incomprehensible statements and scrambling of logical sequences. This worsens in the higher levels, culminating in a simply awful handling of high school physics (more on this later).

In the high school physical science document, inconsistency reigns. Consider, for instance, the following sandwich of a thin slice of trivium between two slabs of sophisticated stuff:

> **Label a periodic table with oxidation numbers of main group elements, identify elements likely to form ions, and use information to construct formulas for compounds.**
>
> **Classify a substance as an element or compound based on its chemical formula or symbol.**
>
> **Explain ionic and covalent bonding based on the oxidation numbers of the elements in a compound. (high school physical science)**

Poor organization goes still further in damaging the internal logic of the subject. For example, electromagnetism and nuclear processes are subsumed under energy conservation—a bewildering choice.

High School Physics

In physics, the standards laudably (and unusually) present information in terms of mathematical equations. Unfortunately, they are set forth in an illogical, nearly nonsensical, and sometimes amusing hodgepodge. For example, the following sequence:

> **Experiment with elastic and inelastic collisions**
>
> **Elastic : $m_1v_1 + m_2v_2 = m_1v_3+m_2v_4$;**
>
> **Inelastic: $m_1v_1+m_2v_2 = (m_1+m_2)v_3$**
>
> **Distinguish between mass and weight using base units in the SI system.**
>
> **Associate time with the independent variable in most experiments. (high school physics)**

Aside from the fact that the subscript notation in the momentum conservation equations is poorly chosen and confusing, what in the world do the last two items have to do with the first, far more sophisticated one?

Thermodynamics is hopeless. Much is omitted, many unimportant matters are stressed, and the logical order more often than not is unruly or even completely inverted. The only section of physics that is not hopelessly scrambled is optics. While not perfect, it makes some sense:

> **Explore properties of electromagnetic radiation.**
>
> **Examine properties of light waves.**
>
> **Investigate the polarization of light.**
>
> **Investigate the optical properties of plane and curved mirrors**
>
> **Focal length:$1/f =1/d_o+1/d_i$;**
>
> **Images in mirrors and lens: $m = h_i/h_o = (-d_i)/d_o$.**

> **Investigate the optical properties of plane and curved mirrors.**
>
> **Draw, explain, and solve problems for the optics of mirrors and lenses.**
>
> **Investigate optical phenomena (i.e., mirage, optical illusions, and dichromatic lens effect).**
>
> **Solve problems related to Snell's law**
>
> > **Index of refraction: $n = (\sin \theta_r / \sin \theta_i)$;**
> >
> > **Snell's law: $n_i \sin \theta_i = n_r \sin \theta_r$.**
>
> **Differentiate among transmission, reflection, refraction, diffraction, and interference of light waves.**
>
> **Explore the formation of color (both additive and subtractive properties) [Additive Color Theory: W= B+G+R: Y= G+R: =B+G: M = R+B; Subtractive Color Theory: B=W–Y: C= W–R: M=W–G]. (high school physics)**

Missing, however, are interference and diffraction (though the section begins with a discussion of the wave nature of light, which should be a fine way of introducing these subjects).

High School Chemistry

Of the two courses covered, Chemistry I appears to be aimed at the traditional high school chemistry course, while Chemistry II is an advanced or honors course. Many of the standards in Chemistry I are well stated—both specific and clearly written. Unfortunately, many others are poorly crafted, or pitched below the level of high school chemistry, or offer spotty coverage of their subject matter. For example, atomic bonding lacks material on the critical topics of hydrogen and metallic bonding; kinetic molecular theory is addressed but the ideal gas law is not; acid-base chemistry is weak and redox reactions are not mentioned; and there is nothing on equilibrium or Le Châtelier's principle, so it is odd to see mention of the use of a solubility product table.

Earth and Space Science

The coverage of earth and space science in Kindergarten through eighth grade is reasonably thorough. The solar system is introduced in third grade and expanded in fourth grade. The universe on the large scale is, however, not mentioned at all.

The Earth's structure, and such effects of plate tectonics as earthquakes, orogeny, and seafloor spreading, are introduced adequately, if a bit late, in seventh grade. The same is true of the rock cycle and mineralogy. The basics of climate and weather are introduced nicely in fourth grade. But it is not easy to tell what students will learn about earth and space science in high school, owing to the wide selection of courses within the category.

Earth science and geology are separate courses, and the treatment of geology in particular has many positive aspects, chief among them a strong section on maps. Although the rigor of many of the standards is far too low for the grade level, some topics—including such high-level topics as crystal systems, systematic mineralogy, and Bowen's Reaction Series—are treated with admirable depth and rigor.

The earth science course covers astronomy at all scales of distance quite thoroughly, beginning with, "Identify the components of the universe: black holes, galaxies, nebulae, solar systems, stars, planets, meteors, comets, and asteroids (high school earth science)," and working down in scale to the effect of the moon and the sun on the Earth's tides.

Life Science

The life science standards suffer from several significant challenges, beginning with poor and repetitive treatment of evolution from Kindergarten through eighth grade. For example, a single guiding question is used to frame every grade, from Kindergarten through grade eight: "How does natural selection explain how organisms have changed over time?"

Fossils are introduced early and often, which is good. Yet by fourth grade the writers seem to have run out of fossil topics. Meaningful statements are replaced by the vague generality, "Gather fossil information to draw conclusions about organisms that exist today," with no indication of what information students should use, or what conclusions students should draw. In fifth grade and beyond, the standards simply repeat concepts previously covered, using different words but with no increase in depth or rigor. For instance, the following standard asks fifth-grade students to:

> **Analyze fossils to demonstrate the connection between organisms and environments that existed in the past and those that currently exist. (grade 5)**

Unfortunately, that task is essentially identical to standards that preceded it in second grade and fourth grade, respectively:

> **Compare pictures of fossils with animals or plants that are living today. (grade 2)**
>
> **Gather fossil information to draw conclusions about organisms that exist today. (grade 4)**

There is a potentially promising exercise at eighth grade: "Create a timeline that illustrates the relative ages of fossils in sedimentary rock layers" and "compare fossils found in sedimentary rock to determine their relative age." Yet the terms "evolution" and "natural selection" are not used. In Biology I, we see the same tendency toward evasion:

> **Apply evidence from the fossil record, comparative anatomy, amino acid sequences, and DNA structure that support modern classification systems. (Biology I)**

And just what are those modern classification systems and what is the basis on which they are built? Tennessee students will never know. Given that biology is an elective in high school and half the biology course options in high school do not entail evolution, it's pretty easy never to learn about it in Tennessee.

Sadly, most important life science topics receive similarly slipshod coverage, with standards that are so vague that they are virtually without content. For instance, seventh-grade students are asked to:

> **Describe the function of different organ systems. (grade 7)**

and

> **Investigate the relationship among DNA, genes, and chromosomes. (grade 7)**

Unfortunately, these expectations provide nothing specific that could be useful to classroom application.

Tennessee presents four biology courses at the high school level: Biology I, Biology II, Human Anatomy and Physiology, and Ecology. Among the four, only Biology II even attempts to cover the full scope of biology, but even there, the standards are often vague and repetitive. Worse still, it isn't clear that all students are required to take Biology II, which means that students could graduate from Tennessee high schools without having been exposed to much of the essential life science content.

Taken together, these flaws earn Tennessee an average score of three out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The clarity of the document does not extend much further than expressing confusion in a grammatically and syntactically correct way. The result is a sort of linguistic bluff: a well-written document that says very little of substance.

Too often, the absence of small details derails an entire statement. For example, in high school chemistry, students must:

> **Determine the colligative properties of a solution based on the molality and freezing point or boiling points of the solvent. (Chemistry I)**

What this confusing statement means is, "calculate the boiling point elevation or the freezing point depression of the solution." An equally confusing statement asks students to:

> **Use calorimetry to: identify unknown substances through specific heat, determine the heat changes in physical and chemical changes, determine the mass of an object, and determine the change in temperature of a material. (Chemistry I)**

Why not simply: "Use the heat capacity equation $Q = mc\Delta T$ to identify a substance by measuring its specific heat capacity in a calorimeter"?

Or consider the following scramble from the physics material:

> **Investigate the definitions of force, work, power, kinetic energy, and potential energy.**
>
> - **Force: $F = ma$;**
> - **Work: $W = Fd$;**
> - **Power: $P = (F\Delta d)/\Delta t$;**
> - **Kinetic Energy: $E_K = 0.5mv^2$;**
> - **Potential Energy: $E_P = mg\Delta h$. (high school physics)**

$F = ma$ is not the definition of force, nor is $E_p = mg\Delta h$ the definition of potential energy. And lumping these equations together adds little value, other than to demonstrate that the writers know them.

Such examples are far from rare. As a result, Tennessee earns an average score of one out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)