SCIENCE

Texas

GRADE	SCORES		TOTAL SCORE
C	Content and Rigor	5/7	6/10
	Clarity and Specificity	1/3	

REPORT CARD

Content & Rigor	**5.0**
Scientific Inquiry & Methodology	7
Physical Science	5
Physics	4
Chemistry	5
Earth & Space Science	6
Life Science	3
Clarity & Specificity	**1.0**

Average numerical evaluations

Document(s) Reviewed

► *Texas Essential Knowledge and Skills for Science*. 2010. Accessed from: http://ritter.tea.state.tx.us/rules/tac/chapter112/index.html

Overview

Texas has produced a set of science standards with areas of strength—including a particularly well-done sequence for earth and space science—but also with weaknesses that cannot be overlooked. These include a tendency across nearly all disciplines to pay lip service to critical content with vague statements, and, somewhat less often, the presence of material that's well below grade level.

Organization of the Standards

The *Texas Essential Knowledge and Skills for Science* (TEKS-Science) consists of a series of rather lengthy outlines that frequently repeat themselves. Standards are presented for each grade, K-8, as well as for eight different high school courses, including biology, chemistry, physics, and integrated physics and chemistry. Further, Texas provides standards for AP Biology, AP Chemistry, AP Physics (both B and C), and AP Environmental Science, as well as for IB Environmental Systems.

For grades K-8, standards are divided into five strands: scientific investigation and reasoning; matter and energy; force, motion, and energy; earth and space; and organisms and environments. Each strand is then divided into one or more sub-strands. Finally, grade-specific standards are provided for each sub-strand.

The high school standards are organized similarly, with two exceptions. First, they are provided by course, rather than by grade. And second, within each course, there are only two strands: scientific processes and science concepts.

One concern with the high school standards is that, in addition to the science courses that are typically offered (chemistry, physics, and biology), the state provides standards for several electives: aquatic science, astronomy, earth and space science, and environmental systems. If students took all of those courses, they would learn a wealth of critical science content. Unfortunately, it's not clear how many of these courses students must take. For the purposes of this review, therefore, we focus mainly on the conventional courses and not the electives.

Content and Rigor

Systematic progress is evident from grade to grade, but in several disciplines the content statements are poorly developed, leaving too much to the imagination. Bringing a bit more detail to the document would go a long way toward improving the Texas standards.

Scientific Inquiry and Methodology

The scientific inquiry and methodology standards are clear, practical, and grade-appropriate, and the content builds well from grade to grade.

History of science is well covered throughout, starting in third grade, when students are asked to "connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists." Here, the explicit connection between conceptual and historical is to be welcomed.

The high school standards are equally strong. Students are expected to evaluate the impact of science on society and the environment and continue their examination of the history of the field. The standards are almost always placed in the context of benchmarks that set reasonable and specific expectations.

Physical Science

The quality of the physical science standards varies dramatically from the highly rigorous and grade-appropriate to the frustratingly general. On the positive side, the terms potential and kinetic energy first appear in sixth grade, and students are expected to differentiate between them. The law of conservation of energy is also well covered, but no mention is made of work or of the work-energy theorem.

Unfortunately, the organization of the physical science standards is problematic. No dedicated physical science strand exists; rather, related content is lumped into one of two categories: "matter and energy" and "force, motion, and energy." As a result, important content is arbitrarily shoehorned into one or the other of these. For example, electromagnetism is subsumed under "force, motion, and energy," for no better reason than that it has to be put somewhere.

Several topics suffer glaring gaps and omissions. Energy, for example, is introduced in fourth grade, but no effort is made to define it, even loosely.

In seventh grade, students are asked to:

> **Illustrate the transformation of energy within an organism such as the transfer from chemical energy to heat and thermal energy in digestion. (grade 7)**

The idea of connecting chemical thermodynamics with metabolism is a good one, but it is marred by the phrase "heat and thermal energy," implying that these are two different things.

The failure to define and develop key concepts is a nagging problem for the physical science material. The term "heat" or "heating" is used some eighteen times from Kindergarten through eighth grade without explanation or connection to particle motion. The term "temperature" is used nine times in those grades but with no discussion of its connection to average molecular kinetic energy. And on the chemical side of physical science, molecules are mentioned in three places, but nowhere is it explained that molecules are made up of atoms. And there is no reference to crystals, let alone their structure.

High School Physics/High School Chemistry

We consider high school physics and chemistry in a single section because of the unconventional way they are blended in the Texas standards. At the high school level, Texas offers Integrated Chemistry and Physics for one credit, specifying that it is intended for ninth or tenth graders. However, the standards contain little that has not already been seen in the middle school grades. There is also a separate chemistry course, recommended for tenth, eleventh, or twelfth grades, and a separate physics course, recommended for ninth, tenth, eleventh, or twelfth grades, with lesser math requirements than the chemistry course. This is unconventional, since the common order of courses is chemistry followed by physics (which is more math-intensive).

In the high school physics course, kinematics and dynamics are introduced systematically and clearly. However, they tend to avoid simple equations that would make the material even clearer and more concise.

There is no systematic coverage of the laws of electromagnetism—Coulomb's, Ampère's, and Faraday's laws in particular. Thermodynamics and kinetic theory are covered, though in a manner far from what would be useful to build a curriculum.

Oscillations, waves, optics, and modern physics receive only sketchy treatment.

Other standards are redundant, riddled with errors, or both. Take, for example, the following:

> **Understand the electromagnetic spectrum and the mathematical relationships between energy, frequency, and wavelength of light. (high school chemistry)**

> **Calculate the wavelength, frequency, and energy of light using Planck's constant and the speed of light. (high school chemistry)**

For starters, students need to know *either* the wavelength or frequency in order to calculate the energy; these variables cannot be found by just knowing the two constants. In addition, these standards are largely redundant. What is missing is a specific listing of what students should know about the electromagnetic spectrum and the connection of spectra to atomic electron transitions.

The quality of the chemistry standards varies widely, from absent to inadequate to excellent. On the one hand, the Texas standards commendably cover several important topics that many other state standards ignore. Those include: accuracy and precision, dimensional analysis, scientific notation, empirical and molecular formulas, the malleability and ductility of metals, and calculations of isotopic composition and atomic mass.

There are, however, substantial gaps. Rates of reaction and chemical equilibrium, for example, are omitted. Also missing is any mention of organic chemistry beyond the sketchy statement that "organic compounds are composed of carbon and other elements," which appears not in high school chemistry, but in seventh grade.

Some of the chemistry standards address topics that are not appropriate for high school. For instance, students are asked to "compare solids, liquids, and gases in terms of compressibility, structure, shape, and volume," a task that younger students could surely handle. By contrast, students are also asked to "classify matter as pure substances or mixtures through investigation of their properties," an expectation that is likely too difficult and time consuming for high school chemistry.

Earth and Space Science

The material for earth and space science is strong, appearing at appropriate grade levels and with sufficient depth. Though a few areas are relatively weak—including aspects of the mechanisms of plate tectonics, earthquakes, and volcanoes—other content is presented with admirable depth and breadth.

Some topics are well introduced, but not adequately developed. For example, students are introduced to the rock cycle in sixth grade, but the standards never discuss the crucial issue of how those processes form a cycle:

> **Classify rocks as metamorphic, igneous, or sedimentary by the processes of their formation. (grade 6)**

The high school earth and space material is especially strong, and much content is covered with depth and rigor. Take, for example:

> **Analyze how gravitational condensation of solar nebular gas and dust can lead to the accretion of planetesimals and protoplanets. (high school earth and space science)**

One may quibble about the instruction to "analyze how"—we presume the intended meaning is simply "explain how"—but the subject is important and appropriate. Similarly strong examples can be found throughout.

To its credit, Texas also dispassionately and unapologetically introduces students to global warming, a political hot potato in many places, with the following:

> **Analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels, and the average global temperature trends over the past 150 years. (high school earth and space science)**

Life Science

In stark contrast to some other disciplines, the Texas life science standards are woefully imbalanced, with poorly developed material in the early grades and strong, sometimes excellent, content in the upper levels.

The subjects of food webs and life cycles, and the idea that offspring are like parents, appear several times from Kindergarten through fifth grade. Unfortunately, there are only minor wording changes—and therefore little increase in depth—over this considerable grade span. Then, out of the blue, fifth-grade students are asked to:

> **Identify the significance of the carbon dioxide-carbon cycle to the survival of plants and animals. (grade 5)**

Given the paucity of prior information, one wonders how this will be accomplished.

Evolution is all but ignored from Kindergarten through fifth grade, save a sentence in the earth and space science section that asks students to "identify fossils as evidence of past living organisms" (grade 5).

The middle school standards are marginally better, but still problematic. For example, seventh graders should learn that:

> **Populations and species demonstrate variation and inherit many of their unique traits through gradual processes over many generations. (grade 7)**

Unfortunately, this is simply wrong. Traits are inherited directly at each generation; there's nothing gradual about it. Students are then asked to explain variation within a population or species by examining external features that enhance survival. Such examinations will yield no explanation of variation.

Perhaps the biggest problem with the middle school standards, however, is their coverage of evolution. For instance, the seventh-grade standards mention the Galapagos finches, giving the impression that the Darwinian paradigm is being presented. Unfortunately, it is not. Instead, the example of the finch *Geospiza fortis* apparently refers to studies by Peter and Rosemary Grant on beak size in this species, made widely known by Jonathan Weiner's Pulitzer Prize-winning book, *The Beak of the Finch*. Creationists often distort these important findings to argue that Darwinian macroevolution does not occur—instead, microevolution does. In addition, the word "evolution" is never used in any of the middle school standards, and the term "natural selection" is never explained.

In spite of the Texas Board of Education's erratic approach to evolution, the state's current high school biology standards handle the subject straightforwardly. There are no concessions to "controversies" or "alternative theories." In fact, the high school biology course is exemplary in its choice and presentation of topics, including its thorough consideration of biological evolution. Even so, the term "natural selection" appears just three times, as does the word "evolution" and its variants. It is hard to see how Texas students will be able to handle this course, given the insufficient foundations offered prior to high school.

In contrast to the confusion of the taxonomic material in sixth grade, the high school standards present a straightforward, if somewhat old-fashioned, version of how taxonomies are constructed.

The only major lapses at the high school level are the rather cursory mentioning of photosynthesis, but not respiration, and the inadequate coverage of genes.

Taken together, the combination of strengths and weaknesses earns the Lone Star State a solid score of five out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The chief problem with the Texas standards is the lack of a red pencil. There are many clear and specific standards, but these are choked by thickets of wordy and repetitious language.

In addition, the standards are sometimes confusing and frustratingly vague. Take, for example, the following process standards:

> **Contrast situations where work is done with different amounts of force to situations where no work is done such as moving a box with a ramp and without a ramp, or standing still.**
>
> **Demonstrate and illustrate forces that affect motion in everyday life such as emergence of seedlings, turgor pressure, and geotropism. (grade 7)**

What these mean is a mystery.

The problem of ambiguity is particularly acute in the physical science material. In fourth grade, for instance, students are expected to:

> **Demonstrate that electricity travels in a closed path, creating an electrical circuit, and explore an electromagnetic field. (grade 4)**

But how fourth graders are supposed to identify, much less explore, an electromagnetic field is unstated, as is how that directive got jammed in with a straightforward item on electric circuits. Equally nebulous standards can be found throughout.

Similarly, too many standards across disciplines ask students to "observe" or "explore," with no indication of what these directions mean or how they are to be measured.

Finally, the organization of the standards is confusing, with related expectations scattered across various strands and sub-strands, making it difficult to track the scope and sequence of important content.

Still, the Texas standards say enough in a sufficiently straightforward manner to earn a one out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)