

SCIENCE

District of Columbia

GRADE SCORES TOTAL SCORE

A

Content and Rigor **7/7**
Clarity and Specificity **3/3**

10/10

REPORT CARD

Content & Rigor **6.7**

Scientific Inquiry & Methodology	5
Physical Science	7
Physics	7
Chemistry	7
Earth & Space Science	7
Life Science	7

Clarity & Specificity **2.6**

Average numerical evaluations

Overview

The District of Columbia’s science standards are among the best we have seen; they are excellent across the board. The one consistent drawback is the inclusion of “examples” that are meant to suggest activities that will help students master the standards. These examples—specifically at the high school level—are often ill-conceived and could distract educators from the otherwise outstanding material.

Organization of the Standards

Grade-specific science standards are presented for each grade, K-8. At the high school level, course-specific (rather than grade-specific) standards are presented for earth science, biology, chemistry, physics, and environmental science.

The K-4 standards are divided into five strands: scientific thinking and inquiry, science and technology, earth science, physical science, and life science. The standards for grades 5-8 are also divided into strands, but these differ based on the grade level, such as “the solar system” in sixth grade and “energy and waves” in eighth grade. Each strand is described by a “broad concept.” For instance, the broad concept for the solar system in sixth grade reads:

Astronomy and planetary exploration reveal the structure and scale of the solar system.

The high school course-specific standards are presented in a parallel manner. For all grades and subjects, strands are then divided into standards, which are listed along with examples that suggest student activities.

Content and Rigor

The D.C. standards are generally clear and rigorous, with content that progresses appropriately through the grades. Science standards in the District are comparable to those from California; both are stellar and either could serve as a national example of excellence. Interestingly, though, the D.C. standards are far more succinct than the California expectations. Yet each covers virtually all of the essential K-12 science content effectively—proving that it’s possible (if difficult) to pull off both brevity and comprehensiveness.

Document(s) Reviewed

► *D.C. Learning Standards: Science*. 2006 (Grades 5 and 8, and Biology updated 2010). Accessed from: <http://dcps.dc.gov/DCPS/In+the+Classroom/What+Students+Are+Learning/What+you+r+child+is+learning+and+expected+to+kno+w+in+grades+K-12#0>

Scientific Inquiry and Methodology

The scientific inquiry and methodology standards are generally clear and appropriately rigorous. Throughout, it is noted that “scientific progress is made by asking relevant questions and conducting careful investigations.” Students in early grades are encouraged to ask, “How do you know?” in “appropriate situations” and to “attempt reasonable answers when others ask the same question.” They are asked to “identify better reasons for believing something” than acceptance of the *status quo* and to “question claims based on vague attributes or on authority...or based on statements made by celebrities or others outside the area of their particular expertise.” These goals continue in the higher grades, where students are asked to consider sample sizes, control groups, biased sampling, and analogy. Though not explicitly tied to content, if taken seriously, these standards could turn D.C. schools into a veritable wellspring of scientific and analytical thinkers!

History of science receives a brief nod in the preamble to the eighth-grade standards. Problematically, only pioneers of physics, cosmology, and “current atomic theory” merit a mention—as if pioneers in other fields are not worth referencing.

Physical Science

As is conventional, the physical science standards for Kindergarten through eighth grade include both physics and chemistry. The development of the physics part is clear and logical. For instance, in third grade, students are instructed to:

- Recognize that energy is needed to carry out almost any kind of change;
- Describe basic forms of energy, including mechanical (kinetic and potential), light, sound, heat, chemical, nuclear, and electrical; and
- Recognize that energy can be transformed from one form to another. (grade 3)

By eighth grade, they are expected to be able to:

- Explain how energy is the ability to do work and is measured in joules;
- Describe kinetic energy as the energy of motion (e.g., a rolling ball), and potential energy as the energy of position or configuration (e.g., a raised object or a compressed spring); and
- Recognize and describe that energy is a property of many systems and can take the forms of mechanical motion, gravitational energy, the energy of electrostatic and magnetostatic fields, sound, heat, and light (electromagnetic field energy). (grade 8)

These examples typify the systematic way in which content builds from grade to grade. Students can acquire a thorough background, preparing them well for the high school level courses.

The chemistry section is equally as rigorous, with atoms, molecules, and ions receiving especially strong coverage:

Recognize that all matter is made of small particles called atoms, which are too small to see with our eyes; describe how atoms may combine to form molecules or crystalline solids (compounds). (grade 5)

Describe how the atoms, molecules, or ions comprising an object are in constant individual motion, and explain how their average motional (kinetic) energy determines the temperature of the object, and how the strength of the forces between them determines the state of matter at that temperature. (grade 8)

High School Physics

The high school physics standards are excellent. Students are asked, for example, to:

Recognize that when a net force, F , acts through a distance, Δx , on an object of mass, m , which is initially at rest, work, $W = F\Delta x$, is done on the object; the object acquires a velocity, v , and a kinetic energy, $K = \frac{1}{2}mv^2 = W = F\Delta x$. (high school physics)

This definition of kinetic energy in terms of the work-energy theorem is exemplary. Similarly, heat and thermodynamics are very well covered, as demonstrated by the following:

- Recognize that heat flow and work are two forms of energy transfer between a system and its surroundings.
- Describe and measure that the change ΔU in the internal energy of a system is equal to the sum of the heat flow, Q , into the system and the work, W , done on the system: $\Delta U = Q + W$ (first law of thermodynamics).
- Describe and measure the work, W , done by a heat engine as the difference between the heat flow, Q_{in} , into the engine at high temperature and the heat flow, Q_{out} , out at a lower temperature: $W = Q_{in} - Q_{out}$. (high school physics)

This is just the beginning of a series of eighteen standards that lays out the subject of thermodynamics in rigorous, logical, and clear fashion. Other areas of physics are comparably well covered.

The one flaw in these otherwise exemplary standards is that the “examples” given by the District are often silly. Here, as

just one example, is what students are to do to understand the concept of entropy:

Students build a tower from dominoes or cards and examine the tendency of those systems toward greater disorder. They discuss the energy that would have to be used to prevent that disorder (e.g., using glue, sealing the tower in a vacuum, etc.). (high school physics)

Sounds like a lot of fun, but it's hard to see how the students' understanding of entropy (defined as $S = Q/T$) will be enriched. To make matters still sillier, one wonders how the students will quantify the energy it takes to use glue, or how a house of cards will become more stable in a vacuum.

High School Chemistry

The District of Columbia's chemistry standards are excellent and cover all of the essential content. Take, for example, the exposition of acid-base chemistry:

Broad Concept: Acids, bases, and salts are three classes of compounds that form ions in water solutions. As a basis for understanding this concept,

Students:

- Explain that strong acids (and bases) fully dissociate and that weak acids (and bases) partially dissociate.
- Define pH as the negative of the logarithm of the hydrogen (hydronium) ion concentration, and calculate pH from concentration data.
- Illustrate and explain the pH scale to characterize acid and base solutions: Neutral solutions have pH 7, acids are less than 7, and bases are greater than 7.
- Describe the observable properties of acids, bases, and salt solutions.
- Explain the Arrhenius theory of acids and bases: An acid donates hydrogen ions (hydronium) and a base donates hydroxide ions to a water solution.
- Explain the Brønsted-Lowry theory of acids and bases: An acid is a hydrogen ion (proton) donor, and a base is a hydrogen ion (proton) acceptor. (high school chemistry)

This is as clear as it is precise.

Unfortunately, coupled with these excellent standards are a series of inane, confusing, or plainly wrong “examples.” As impressive as the District's chemistry standards are, their examples are equally as appalling, as in the following:

Students conduct a titration experiment involving an acid and a base (vinegar and ammonia) using phenolphthalein as an indicator, and they relate it to a human condition,

such as heartburn, which is associated with acid indigestion and sour stomach that requires the intake of an antacid for relief. (high school chemistry)

Titration is a useful exercise, but the implication that the human stomach is normally neutral (pH 7.0) is far from the truth.

Another example:

Students determine the molar mass of 0.650 g of O₂ gas in 100.0 mL at STP.

The writers of these examples—who could not possibly have been the same people to author the first-rate chemistry standards—seem unaware of the fact that no calculations are necessary for this. The molar mass of O₂ gas is 32 g/mole.

Earth and Space Science

As with the other content areas, the coverage of earth and space sciences is excellent across all grade levels. The treatment of astronomy is particularly strong. For example, students are asked to:

Observe how telescopes are used both to magnify images of distant objects in the sky, including the moon and the planets, and to gather enough light from very dim objects to make them visible. ... Observe and describe that stars vary in size, but they are so far away that they look like points of light. (grade 5)

This may be the only standard across the board that makes explicit the fact that while planets can be magnified by telescopes, stars are so distant that they cannot be magnified, and the function of the telescope is to gather more light.

Sixth grade features an elegant link between both thinking about planetary evolution in terms of sedimentary rocks and the findings of fossils in these strata, and then segues into biological evolution:

Explain how physical evidence, such as fossils and surface features of glaciation, supports detailed explanations of how Earth's surface has evolved over geologic time. (grade 6)

Observe and explain that fossils provide evidence of how life and environmental conditions have changed. (grade 6)

But again, the fine exposition is occasionally marred by examples that don't match the rigor of the material. For instance, in fourth grade, following the broad concept “energy and matter have multiple forms and can be changed from one form to another,” comes:

Students take an ‘energy’ journey. They pretend they are photons of light that come from the sun, onto a plant, eaten by a dinosaur, which was eaten by another dinosaur. They explain their “energy” journey into forming molecules that made the dinosaur live, move, die, decompose, and reform into a fossil fuel. (grade 4)

Oil comes from dinosaurs only in 1970s Chevron cartoon commercials. What will students say about the transformation of their photons to bonds in carbon chains?

Similarly, in sixth grade, students are asked to:

Measure the latent heat of water by taking the temperature of ice as it melts to water and water as it boils. Students relate this information to recent data on the suspected effects of global warming on glaciers. (grade 6)

Students won’t see any temperature change during the phase change; they would need some sort of calorimeter. They could notice that heat is being absorbed without a temperature change, which doesn’t measure the latent heat but suggests it exists.

Life Science

The District of Columbia’s life science standards are thorough, well developed, and appropriately rigorous. They could easily serve as a model for other states. Even the examples (criticized in other disciplines) are well handled, especially in the early grades.

One noteworthy example, from fourth grade, is the “broad concept” of the various mechanisms human beings employ to combat disease. Through nine well-ordered steps, students are taught the basics of the immune system, the nature of pathogens, and the importance of vaccines. None of this is over the head of a fourth grader, yet something this sophisticated and interesting is not often presented, even in high school.

Seventh grade covers biology at a level often found in high school standards. As with the earlier example about human defenses, the consideration of evolution is thorough and sophisticated.

High school biology is still more sophisticated, yet totally accessible to students who have had the grade-by-grade preparation outlined in the document. It begins with biochemistry, which few states do, and provides a thorough presentation of cell biology, genetics, evolution, physiology, and ecology.

Clear, rigorous, and comprehensive, the D.C. standards could easily stand as a national model to guide curriculum and instruction from Kindergarten through high school. The most significant flaw is the inclusion of poor support examples at the high school level. Because all of the critical content is covered—and covered well—by the standards, the District earns a seven out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The D.C. science standards are clear, succinct, and specific. They could easily guide rigorous curriculum and assessment development across all grades, from Kindergarten through high school.

As mentioned above, the District also provides “examples” that are meant to describe instructional activities that can help students master particular concepts. From Kindergarten through seventh grade, these examples often describe fruitful student activities (eighth grade offers no examples). Take, for instance, the following:

Students discuss the turtles, finches, and lizards unique to each of the Galapagos Islands and relate these phenomena to Darwin’s natural selection. (grade 7)

Students design and build a sundial (with support from the teacher) and use it to determine the time of day. They explore how accurate it is over time and determine the conditions under which the sundial does and does not work. (grade 3)

Students observe and sketch crystalline structures of common minerals, such as quartz (resistant to weathering), mica (breaks down into thin, flexible shiny sheets), and calcite (soft mineral), and list the chemical compositions of each. (grade 6)

Unfortunately, the high school examples (as discussed above) are far inferior, often bordering on the absurd.

Fortunately, the flaws are limited to the high school examples, meaning that the District scores a perfect three out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)