SCIENCE

# Ohio

| GRADE | SCORES | | TOTAL SCORE |
|---|---|---|---|
| B | Content and Rigor | 5/7 | 7/10 |
| | Clarity and Specificity | 2/3 | |

**REPORT CARD**

| | |
|---|---|
| **Content & Rigor** | **4.8** |
| Scientific Inquiry & Methodology | 2 |
| Physical Science | 6 |
| Physics | 4 |
| Chemistry | 6 |
| Earth & Space Science | 6 |
| Life Science | 5 |
| **Clarity & Specificity** | **1.8** |

*Average numerical evaluations*

### Document(s) Reviewed[1]

- *Ohio Revised Science Standards and Model Curriculum: Grades PreK through Eight*. 2011. Accessed from: http://www.ode.state.oh.us/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=107333
- *Ohio Revised Science Standards and Model Curriculum: High School*. 2011. Accessed from: http://www.ode.state.oh.us/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=105412

[1] In this review, we examine Ohio's recently adopted (2011) science standards. While these are now the state's official science standards, teachers are still directed to use the 2002 standards until assessments aligned with the 2011 standards are implemented "in several years." So while the 2011 standards examined here are not currently in use, this review will help guide Ohio when deciding whether to adopt the Next Generation Science Standards (see Introduction). A review of Ohio's 2002 standards can be found here: http://www.edexcellence.net/publications-issues/publications/sosscience05.html.

## Overview

The documents that comprise the Ohio science standards are excessively long (four hundred pages), making it difficult to wade through the material to tease out the essential content. That said, educators with sufficient endurance will be able to find reasonably rigorous K-12 science content that can become a solid foundation for effective curricula, instruction, and assessment.

## Organization of the Standards

The Ohio preK-8 science standards are divided into three strands: earth and space science, physical science, and life science. For each strand, a series of topics are then presented. For instance, topics within the earth and space science strand include "Earth's surface" and "cycles and patterns in the solar system." These are followed by grade-specific standards, called "content statements." For each content statement, the state provides a series of "content elaborations," which are several-paragraph descriptions of how the content statements relate to those of previous and later grades. The content elaborations also provide more detailed descriptions of what students should know about each topic.

Along with the content expectations, Ohio's standards and curriculum document is chockablock with additional material. For instance, each topic includes an inquiry-based "expectations for learning" section (apart from the inquiry standards themselves), a series of model classroom lessons, and advice on how to handle diverse learners.

Ohio's high school standards and curricula are organized similarly, though material is presented by course instead of grade for the following courses: introductory physical science, introductory biology, advanced chemistry, environmental science, physical geology, and physics.

## Content and Rigor

The scientific content in the Ohio standards starts strong and, refreshingly, gains strength with advancing grade levels. Nuggets of excellent material emerge with increasing frequency through the middle school years and into high school (though a great deal of content is missing from high school physics). Generally, content statements are carefully written, scientifically accurate, and elegantly presented.

### Scientific Inquiry and Methodology

The standards set forth brief goals, repeated across grades, for the state's "science inquiry and applications" section. There are six for pre-Kindergarten through fourth grade, eight for grades five through eight, and six for high school. Students are expected to become proficient in these as they "construct their knowledge and understanding in all science content areas." Ironically, given the verbosity of the rest of the material, the goals are often briefer than they ought to be. For example, between pre-Kindergarten and fourth grade, students will "plan and conduct simple investigations," but when one looks at the actual standards it is difficult to ascertain how this skill is to develop over the six-year period.

While it is important for states to embed their process and inquiry standards within their content standards, Ohio does this in such a way as to obscure what skills students should master. Worse, the related classroom examples (e.g., "plan and implement a scientific experiment" in fifth grade) add little value.

Similarly empty standards can be found at the high school level. For instance, a section called "visions into practice," mentions the history of science and directs students to "develop a timeline from Mendel's, Darwin's, and Wallace's work to the present day," but it's unclear *why* students should engage in such an exercise.

### Physical Science

Physical science is presented in narrative form, rather than lists of content, and the result is a clear exposition of essential content (albeit with a few important topics missing, including the mole concept and the writing and balancing of chemical equations). For some reason, all mention of atoms, displacement, and velocity is deferred until high school, as is all quantitative work.

Physical concepts at the elementary levels are beautifully treated. In second grade, for example:

> **Forces are needed to change the movement (speed up, slow down, change direction or stop) of an object. Some forces may act when an object is in contact with another object (e.g., pushing or pulling). Other forces may act when objects are not in contact with each other (e.g., magnetic or gravitational). (grade 2)**

In fourth grade, a writer who clearly understands physics introduces the tricky concept of heat:

> **The word "heat" is used loosely in everyday language, yet it has a very specific scientific meaning. … An object has thermal energy due to the random movement of the particles that make up the object. … "Heating" is used to describe the transfer of thermal or radiant energy to another object or place. Differentiating between these concepts is inappropriate at this grade level. … However, the word "heat" has been used with care so it refers to a *transfer* of thermal or radiant energy. (grade 4)**

This statement is correct, well crafted, and admirably rigorous for the grade level.

Further, the treatment of physical science in ninth grade offers a nice overview of Newtonian mechanics, quite reasonably limited to one-dimensional cases.

### High School Physics

The coverage of some basic high school physics topics is clear and thorough. The course begins with a fine treatment of kinematics in one and two dimensions, based on a recapitulation of what the student already knows from the preceding physical science material. This is followed by detailed discussion of graphing (position, velocity, and acceleration as functions of time) and of motion in one and two dimensions, exemplified by free fall and projectile motion. A thorough treatment of dynamics logically follows, using Newton's laws to analyze Atwood's machines and applying them to gravitational, elastic, frictional, and hydrodynamic forces, with special attention to curvilinear motion.

Momentum and impulse are treated especially well, as is mechanical energy (though nuclear energy is rather incongruously introduced at this point).

A well-written section on waves and optics follows, and then a section on electromagnetism. There are fine treatments here of electrostatics and Coulomb's law, which is laudably and explicitly stated through its mathematical expression ($F_e = k_e q_1 q_2 / r^2$), ensuring that students know more than just the concept of the law, but how to apply it. This is followed by a discussion of electric fields and potentials, and some practical applications to electric circuits. However, electromagnetism is dealt with somewhat sketchily, with no mention of Ampère's or Faraday's laws.

Unfortunately, a great deal of important material is missing. Modern physics (with the exception of a brief citation of nuclear energy) is not covered at all; neither is thermal physics. In fact, a discussion of conservation of energy makes no mention of heat energy. Indeed, a search of the entire high school physics material reveals not a single use of the words "heat" or "thermal." Given that the subject was introduced at the lower physical science level, it is odd that it is slighted here.

### High School Chemistry

Like the other high school courses, chemistry is presented as an outline followed by a series of fairly lengthy essays which cover the subject matter. Here is a typical example:

> **Properties of acids and bases and the ranges of the pH scale were introduced in middle school. In [high school] chemistry, the structural features of molecules are explored to further understand acids and bases. Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion ($H_3O^+$). The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. Bases are likely to dissociate in water to form a hydroxide ion. Acids can react with bases to form a salt and water. Such neutralization reactions can be studied quantitatively by performing titration experiments. Detailed instruction about the equilibrium of acids and bases and the concept of Brønsted-Lowry and Lewis acids and bases will not be assessed at this level. (high school chemistry)**

Generally, this coverage is clear and complete, as well as carefully integrated into what students have already learned—with the exception that both the Brønsted-Lowry and Lewis definitions of acids and bases are explicitly excluded. It is disappointing to see such limits placed on student exploration. And, unfortunately, other important topics are similarly—and unnecessarily—limited.

This tendency to leave out reasonable high school chemistry content or, as in the example above, specifically omit it, weakens what otherwise would serve as superior standards.

### Earth and Space Science

Earth and space science gets off to a typically slow start, with little substance in the primary grades. But once the standards pick up speed, there is much terrific material, as in the following:

> **The distance from the sun, size, composition and movement of each planet are unique. Planets revolve around the sun in elliptical orbits. Some of the planets have moons and/or debris that orbit them. Comets, asteroids and meteoroids orbit the sun. (grade 5)**

The treatment of minerals is also exceptional, as is that of earth-surface features in eighth grade. With that level of detail, however, small errors occasionally creep in, such as in the following:

> **Historical data and observations such as fossil distribution, paleomagnetism, continental drift and sea-floor spreading contributed to the theory of plate tectonics. The rigid tectonic plates move with the molten rock and magma beneath them in the upper mantle. (grade 8)**

Plates are made of lithosphere rather than crust, and for the most part the mantle is not molten.

Such flaws are minor, however, and are more than balanced by many praiseworthy entries. (Even the statement above has redeeming qualities—it touches on the evidence for plate-tectonic theory, for example, which many states ignore.)

The organization of the high school material is a bit quirky—though the quirks don't necessarily distract from strong coverage of important topics. The astronomy content usually found in earth and space science instead appears in the physical science course. But there, it is handled exceptionally well. The content elaboration for "stars" offers just one example of complete and helpful information:

> **Early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. When heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. These and other fusion processes in stars have led to the formation of all the other elements. (NAEP 2009). All of the elements, except for hydrogen and helium, originated from the nuclear fusion reactions of stars (College Board Standards for College Success, 2009). (high school physical science)**

Further, the high school physical geology material is elegant and ambitious, incorporating chemistry, physics, and environmental science—though sometimes just in keyword-outline form. Advanced topics with high explanatory value, such as isostasy, are presented.

### Life Science

The Ohio life science standards are generally strong and include much essential content. Mendelian genetics, for example, is well treated in eighth grade and evolution receives strong coverage throughout. Fossils are covered in second, fourth, and eighth grades, and a major unit in high school readdresses the topic thoroughly, including common descent, deep time, and cladistics. Evolution is firmly grounded as the central concept of the life sciences:

> **Biological evolution explains the natural origins for the diversity of life. Emphasis shifts from thinking in terms of selection of individuals with a particular trait to changing proportions of a trait in populations. The study of evolution must include Modern Synthesis, the unification of genetics and evolution and historical perspectives of evolutionary theory. The study of evolution must include gene flow, mutation, speciation, natural selection, genetic drift, sexual selection and Hardy Weinberg's law [*sic*]. (high school biology)**

There is considerably more of this clear and detailed development of evolution standards. The mention of genetic drift—a rarity in state science standards—deserves particular mention. (The overall quality of the passage is such that we can forgive the writer who imagined that Hardy Weinberg was a single person and thus muddled the Hardy-Weinberg law.)

The largest omissions from the life science standards are of organ systems and physiology. Neither is covered at any grade level—a search of both the elementary and high school documents yields no reference to nerves, hormones, or digestion.

The content that Ohio does cover is strong across all subjects. However, key omissions, especially in high school physics and in life science, bring the Buckeye State's average content and rigor score down to a five out of seven. (See Appendix A: Methods, Criteria, and Grading Metric.)

## Clarity and Specificity

The most significant shortcoming of the Ohio science standards is the sheer volume of the materials. Combining the standards with the model curriculum does not help.

Some of the supplementary material, however, does serve to clarify expectations. For instance, the state has added lists of common misconceptions, which will be of particular use to inexperienced teachers:

> **Although two materials are required for the dissolving process, children tend to focus only on the solid and they regard the process as melting…When things dissolve they disappear. Melting and dissolving are confused. (grade 1)**

However, one must wade through a great deal of boilerplate to find the useful material—a sometimes frustrating and always time-consuming experience. All in all, Ohio has produced a fine set of science standards nestled within a great deal of verbiage. Fortunately, the documents tend to be well written, if not precisely to the point. As such, Ohio earns a commendable two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)