SCIENCE

Indiana

GRADE	SCORES		TOTAL SCORE
A-	Content and Rigor	6/7	9/10
	Clarity and Specificity	3/3	

REPORT CARD

Content & Rigor	**6.2**
Scientific Inquiry & Methodology	7
Physical Science	5
Physics	5
Chemistry	7
Earth & Space Science	6
Life Science	7
Clarity & Specificity	**2.8**

Average numerical evaluations

Overview

The Indiana science standards are clear and rigorous, with particular strength at the high school level in chemistry, earth and space science, and life science. The materials are occasionally marred by the omission of important content and a general lack of specificity that undermines their overall effectiveness. But even with these flaws, the document contains the fundamentals for a balanced, effective curriculum.

Organization of the Standards

Indiana presents grade-specific standards for grades K-8 and course-specific high school standards for Biology I, Chemistry I, Physics I, Earth and Space Science I, Integrated Chemistry-Physics, and Human Anatomy and Physiology.

At each grade level, K-8, the standards are divided first into strands. There are four strands in Kindergarten (nature of science, physical science, earth science, and life science), and five in grades 1-8 (nature of science; design process; physical science; earth science; life science; and science, technology, and engineering). At the high school level, the standards are organized similarly, except that benchmarks are presented by course, rather than by grade.

In addition, for grades 6-8 and high school, the state provides a "reading for literature in science" and "writing for literature in science" strand.

Content and Rigor

Indiana has a long history of producing very good science standards. This latest version is consistent with that laudable tradition. The document lays out key content in clear prose, building logically and effectively through advancing grade levels with refreshing precision. Expectations are both reasonable and rigorous.

Scientific Inquiry and Methodology

Indiana lays out a worthy set of process standards. Teachers are presented with principles that are meant to be "integrated into the curriculum along with the content standards on a daily basis." Generally these principles are clearly stated, although there is some regrettable reference to the nebulous act of "brainstorming" solutions

Document(s) Reviewed

- *Indiana Academic Standards for Science.* 2010. Accessed from: http://dc.doe.in.gov/Standards/AcademicStandards/PrintLibrary/science.shtml to problems. Of particular note is how, in sixth grade and beyond, reading and writing for literacy in science is integrated into the classroom, emphasizing that "instruction in reading, writing, speaking, listening, and language" is not solely the province of the humanities instructor. The principles of literacy in science are clearly stated, appropriate, and should be adopted by other states.

Methodology is nicely integrated into the content matter, is presented at reasonable length and depth, and is never used as a hand-waving mechanism to hide the absence or paucity of content.

Physical Science

The physical science standards are generally clear, thorough, and appropriately rigorous. Take, for example, the following first-grade standard:

> **Experiment with simple methods for separating solids and liquids based on their physical properties. (grade 1)**

It's nice that this common first-grade task—distinguishing between solids and liquids—is couched in experimental terms.

Similarly, the following sixth-grade standards are strong:

> **Recognize that objects in motion have kinetic energy and objects at rest have potential energy.**
>
> **Describe with examples that potential energy exists in several different forms (e.g., gravitational potential energy, elastic potential energy and chemical potential energy).**
>
> **Compare and contrast potential and kinetic energy and how they can be transformed from one form to another.**
>
> **Explain that energy may be manifested as heat, light, electricity, mechanical motion, and sound and is often associated with chemical reactions. (grade 6)**

Unfortunately, the standards suffer from a few drawbacks. Energy is first defined in seventh grade only as "the capacity to do work," a fairly loose definition that belongs three or four grades earlier. By waiting so long to introduce energy and not treating it in more depth, the standards do not prepare students for later study. Complicating matters, the student is required in fourth grade to "provide evidence that heat and electricity are forms of energy," never having been provided with a clue as to what energy is, let alone how one would identify forms of it.

There are some other minor weaknesses. For instance, in third grade, students are asked to:

> **Investigate how the loudness and pitch of sound changes when the rate of vibrations changes. (grade 3)**

But the effect of "rate of vibrations" (i.e., frequency) on intensity is nonexistent, and its effect on the related physiological property pitch is a second-order effect far beyond the scope of third-grade studies.

High School Physics

Hurrah! The high school physics materials actually begin with kinematics and then follow up with dynamics before going on to other things. This is rare and laudable. It does give one pause, however, to see all of Newton's three laws (plus some other items such as free-body diagrams) shoehorned into one single high school standard.

The standards also address heat and thermodynamics in a logical way, even asking the student to derive the ideal gas law from the kinetic molecular model—although somehow the equation $pV = nRT$ never appears. Nor do the second law or heat engines.

Electricity and magnetism are introduced with the logical progression provided by Coulomb's law: electric field–electric potential–electric current. But after this good start, the integration of electricity and magnetism into electromagnetism is barely touched upon and neither Ampère's law nor Faraday's law appears.

High School Chemistry

Curricula based on the Indiana chemistry standards would prepare students reasonably well for a first-year college chemistry course. That said, there are some problems and deficiencies. Le Châtelier's principle, which describes the effects of a disturbance on a system in equilibrium, is missing, as are Lewis dot structures and molecular shapes and polarities.

Overall, however, these chemistry standards are extremely impressive and would serve as a worthy model for most other states. While many state standards documents do not mention calculations at all, Indiana presents more than ten chemistry standards that call for calculations and problem solving. These cover such diverse topics as percent composition, equation stoichiometry, gas laws, half-life, and calorimetry.

Curiously, the standards include expectations for a high school integrated chemistry and physics course. While it contains some good material, the content seems too rigorous for an eighth/ninth-grade physical science course. At the same time, it cannot carry the burden of the standard one-year high school chemistry and physics courses. These last two, in any case, have their own standards, both of which are good.

Earth and Space Science

The earth and space science standards are a pleasure to read, competently—often elegantly—written, and well organized. They develop a great deal of interesting content. For example, the following standards demonstrate how students are introduced to soils in first grade:

> **Observe and compare properties of sand, clay, silt, and organic matter. Look for evidence of sand, clay, silt, and organic matter as components of soil samples.**
>
> **Choose, test, and use tools to separate soil samples into component parts.**
>
> **Observe a variety of soil samples and describe in words and pictures the soil properties in terms of color, particle size and shape, texture, and recognizable living and nonliving items.**
>
> **Observe over time the effect of organisms like earthworms in the formation of soil from dead plants. Discuss the importance of earthworms in soil. (grade 1)**

These simple exercises are gradually built upon, so that by the time the student reaches fourth grade, they are expected to do the following:

> **Demonstrate and describe how smaller rocks come from the breakage and weathering of larger rocks in a process that occurs over a long period of time.**
>
> **Describe how wind, water, and glacial ice shape and reshape earth's land surface by eroding rock and soil in some areas and depositing them in other areas in a process that occurs over a long period of time.**
>
> **Describe how earthquakes, volcanoes, and landslides suddenly change the shape of the land.
> (grade 4)**

Other topics, such as solar system astronomy, are dealt with equally well.

Some important content is missing, particularly astronomical, tectonic, and climate detail in the elementary grades. But there is still plenty for a good elementary science program and the high school content borders on excellent. For instance, high school students are to learn about solar system formation, the Herzsprung-Russell diagram, Hubble's law and the Big Bang, and the general structure of the universe.

This is a thorough and systematic introduction to the essential concepts of cosmology.

Life Science

The life science material flows nicely and the concepts are well integrated. Here, for example, is the treatment of embryology in seventh grade:

> **Explain that after fertilization a small cluster of cells divides to form the basic tissues of an embryo and further develops into all the specialized tissues and organs within a multicellular organism. (grade 7)**

The material on heredity is also presented in depth at this level, asking students to "understand the relationship between deoxyribonucleic acid (DNA), genes, and chromosomes" (grade 8).

The terms evolution, natural selection, common ancestry, and so on are notable for their absence from Kindergarten through eighth grade. The most we get in eighth grade is:

> **Describe the effect of environmental changes on populations of organisms when their adaptive characteristics put them at a disadvantage for survival. Describe how extinction of a species can ultimately result from a disadvantage. (grade 8)**

By contrast, the coverage of evolution at the high school level is excellent.

Metabolism and photosynthesis are also covered in detail at the high school level, and there is a smooth continuation of embryology with the following:

> **Understand that most cells of a multicellular organism contain the same genes but develop from a single cell (e.g., a fertilized egg) in different ways due to differential gene expression. (Biology I)**

Heredity is covered equally well.

Many of the high school standards are particularly sophisticated, including:

> **Recognize that traits can be structural, physiological, or behavioral and can include readily observable characteristics at the organismal level or less recognizable features at the molecular and cellular level. (Biology I)**

Essentially all of the biology material pertinent to physiology is contained in the separate document on anatomy and physiology standards. While the material is excellent, this is presumably an add-on course, meaning that few students will learn this important segment of biology.

With a few exceptions, discussed above, the Indiana standards are rigorous and thorough, covering much of the critical K-12 science content. As a result, Indiana earns a six out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Indiana standards are presented in a clear and easy-to-follow outline. As an unintended consequence, the knowledgeable reader has no trouble spotting the gaps, discussed in detail above. But the expectations that are included are written in unambiguous language and are specific enough to support the development of a rigorous K-12 science curriculum. Consequently, Indiana earns an impressive average score of three out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)