SCIENCE

Missouri

GRADE: C

SCORES

Content and Rigor **4/7**
Clarity and Specificity **2/3**

TOTAL SCORE: 6/10

REPORT CARD

Content & Rigor	**3.7**
Scientific Inquiry & Methodology	5
Physical Science	4
Physics	0
Chemistry	2
Earth & Space Science	5
Life Science	6
Clarity & Specificity	**2.3**

Average numerical evaluations

Overview

The Missouri standards present a mixed picture, varying in quality from quite good (for K-8 life science) to essentially useless (for high school physics). Most material lies between these extremes.

Organization of the Standards

The K-8 Missouri standards are first divided into eight strands: matter and energy; force and motion; living organisms; ecology; earth systems; universe; scientific inquiry; and science, technology, and human activity. Each strand is then divided into sub-strands, then into "standards" which are common across all grades. These standards are then explained by grade-specific learning objectives. For example, under the "properties and principles of matter and energy" strand, the first sub-strand indicates that "changes in properties and states of matter provide evidence of the atomic theory of matter." A standard listed under this sub-strand further explains that "objects, and the materials they are made of, have properties that can be used to describe and classify them." And a first-grade learning objective linked to that standard asks students to: "Order objects according to mass."

The high school standards are organized similarly, except that they are presented by course (rather than by grade) for Biology I, Physical Science, Physics I, Chemistry I, and Earth and Space Science.

Oddly, there are standards for high school biology (presented with the K-8 standards) as well as for Biology I (presented with the other high school courses). While the distinction between biology and Biology I is not completely clear, we infer that the former is relevant to the traditional high school biology course, and it is the one considered in this review.

Content and Rigor

The best of the Missouri standards typically appears in the earlier grades. As grade levels rise, the content becomes increasingly prone to error.

Document(s) Reviewed

- *Missouri Grade and Course Level Expectations: K-5, 6-8, Biology*. November 2008. Accessed from: http://www.dese.mo.gov/divimprove/curriculum/GLE/
- *Missouri Course-Level Expectations: Other Science Courses*. June 2007. Accessed from: http://www.dese.mo.gov/divimprove/curriculum/GLE/documents/cur-sc-other-cle-1107.pdf

Scientific Inquiry and Methodology

The Missouri standards offer a number of refreshing observations, from acknowledging that there is no rigid procedure called "the scientific method" to the consideration that gender and ethnicity can influence scientific conduct. Students are thus presented with a more realistic depiction of the scientific endeavor. Throughout, there is a good dose of realism about the scientific process and the social and historical aspects of the scientific enterprise. Process material builds up gradually, appropriately, and logically across grades.

There is, however, some confusion. Within the "scientific inquiry" strand, one sub-strand states that "the nature of science relies upon communication of results and justification of explanations." The stated expectations, however, deal almost exclusively with presentation of results. The issue of justification is dealt with more properly in the previous sub-strand, which states that "scientific inquiry includes evaluation of explanations (laws/principles, theories/models) in light of evidence (data) and scientific principles (understandings)."

Elsewhere, students are asked to analyze "whether evidence (data) and scientific principles support proposed explanations (laws/principles, theories/models)." But laws don't *explain* anything—they make statements. And theories rise above the status of proposed explanation. A similar confusion arises in one of the historical strands, where hypotheses are conflated with "accepted ideas" such as laws and theories. Disturbingly, this same strand calls on students to "identify and analyze current theories that are being questioned, and compare them to new theories that have emerged to challenge older ones." The examples given—the political whipping boys of global warming and "theories" of evolution—are not theories being questioned within the scientific community; in this case, one must conclude that political considerations have trumped science in the writing of the standards.

Physical Science/High School Physics

From Kindergarten through eighth grade, physical science is generally strong, and the coverage of energy is especially impressive. At elementary levels, the problem of making a satisfactory, usable definition of energy is a knotty one, but Missouri addresses it in an interesting and useful way with the following standard:

> **Forms of energy have a source, a means of transfer (work and heat), and a receiver. (grades K-8)**

In this context, sound is investigated in Kindergarten and second grade, heat in first and third grades, light in third and fifth grades, and electric circuits in fourth grade.

Mechanics is addressed clearly and the standards increase in depth and rigor from grade to grade.

There are some scientific errors, however, and the number of these errors increases as grade levels rise. Take, for example, the following sixth-grade standard:

> **Describe how changes in energy cause changes in loudness and pitch of a sound. (grade 6)**

Loudness is certainly associated with energy density, but pitch is another matter. Frequency does appear in the mathematical expression for energy flux of a wave, but surely this is not what is intended for sixth graders.

Then, in seventh grade, students are asked to:

> **Describe the interactions (i.e., repel, attract) of like and unlike charges (i.e., magnetic, static electric, electrical). (grade 7)**

What that means is anyone's guess. Magnetic forces do not have anything to do with charges, and it is impossible to tell what distinction is intended between "static electric" and "electrical."

The high school physics standards often ask little more than the standards for Kindergarten through eighth grade. For example, a high school standard (listed for high school physical science, Physics I, Chemistry I, and Earth and Space Science) asks students to:

> **Classify the different ways to store energy (i.e., chemical, nuclear, thermal, mechanical, electromagnetic) and describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant, within a system (e.g., using gasoline to move a car, photocell generating electricity, electromagnetic motor doing work, energy generated by nuclear reactor). (high school)**

This standard is no more sophisticated than what was included in the standards prior to high school.

Similarly, high school students are asked to "describe the force(s) that keep an object traveling in a circular path." But again, this is just a version, stated less clearly, of an earlier standard: "Describe the circular motion of a moving object as the result of a force acting toward the center" (grade 7).

High School Chemistry

Like the high school physics standards, far too many of the high school chemistry indicators ask far too little of students. Take, for example, the following:

> **Calculate the number of protons, neutrons, and electrons of an isotope, given its mass number and atomic number. (Chemistry I)**

Certainly more can be expected of high school students.

Other standards are overly simplistic or trivial. For instance:

> **Classify a substance as being made up of one kind of atom (element) or a compound when given the molecular formula or structural formula (or electron dot diagram) for the substance. (Chemistry I)**

In all, there is simply too little substance in the chemistry standards to guide a rigorous, high school level curriculum.

Earth and Space Science

Overall, the earth and space science standards are well written, logical, and free from obvious error; many topics are addressed with sufficient depth and rigor. Plate tectonics, climate, and weather are all well covered. Content in the elementary grades is quite complete.

But a few items of important content are missing or underdeveloped. For example, although the increasing distances between galaxies is mentioned, the evidence for this expansion and its implications for possible origins of the universe are not explained; the Big Bang gets only a glancing mention in the Impact of Science section.

Relative dating methods are introduced in eighth grade with this entry: "Use evidence from relative and real dating techniques (e.g., correlation of trace fossils, landforms, and rock sequences; evidence of climate changes; presence of intrusions and faults; magnetic orientation; relative age of drill samples) to infer geologic history." But aside from the fact that the term "real" is probably a stab at "absolute," absolute dating methods aren't at all explained. Earthquakes and volcanoes get short shrift for the interesting phenomena they are, mentioned only as hazards and effects of plate tectonics (which get better treatment). There is good reference to evidence of climate change—both natural and human—but, oddly, no explanation of important mechanisms such as the greenhouse effect.

Life Science

Though not perfect, the best coverage by far is in the life sciences. There is a substantial amount of good material in eighth grade on heredity, cells, and physiology. As one example, "Identify and contrast the structures of plants and animals that serve similar functions (e.g., taking in water and oxygen, support, response to stimuli, obtaining energy, circulation, digestion, excretion, reproduction)." Eighth grade also includes solid material on diseases.

At the high school level, an item marked with an asterisk "indicates that it is a local assessment item"—in other words, it will not be covered on the statewide exams. Unfortunately, quite a lot of the material on evolution is treated in this way. For example, the following standards are asterisked:

> **Explain how similarities used to group taxa might reflect evolutionary relationships (e.g., similarities in DNA and protein structures, internal anatomical features, patterns of development).**
>
> **Explain how and why the classification of any taxon might change as more is learned about the organisms assigned to that taxon.**
>
> **Recognize that degree of relatedness can be determined by comparing DNA sequences.**
>
> **Interpret fossil evidence to explain the relatedness of organisms using the principles of superposition and fossil correlation.**
>
> **Evaluate the evidence that supports the theory of biological evolution (e.g., fossil records, similarities between DNA and protein structures, similarities between developmental stages of organisms, homologous and vestigial structures). (Biology I)**

By contrast, the following evolution topics do not have an asterisk:

> **Explain the importance of reproduction to the survival of a species (i.e., the failure of a species to reproduce will lead to extinction of that species).**
>
> **Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) and describe how that variation may have provided populations an advantage for survival.**
>
> **Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. (Biology I)**

In other words, all evolution material that might be considered controversial is categorized as being subject to local assessment and thus exempt from wider examination at the state level.

Taken together, the Missouri science standards earn a middling four out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Missouri standards are, for the most part, clearly written. Unfortunately, when they stumble, we find confusing hodgepodges like this: “Identify pure substances by their physical and chemical properties (i.e., color, luster/reflectivity, hardness, conductivity, density, pH, melting point, boiling point, specific heat, solubility, phase at room temperature, chemical reactivity)” (high school).

In addition, the standards vary widely in specificity, and syntax is often at the root of the problem. In physical science, for example, students are asked to:

> **Identify magnets cause some objects to move without touching them. (Kindergarten)**
>
> **Identify magnets attract and repel each other and certain materials. (grade 2)**
>
> **Identify matter is anything that has mass and volume. (grade 6)**

This silliness seems to arise from the misuse of the verb “identify,” because it occurs frequently in a variety of contexts. Another example is the standard’s frequent error in measuring forces in “Newton’s,” instead of newtons.

The overall score for clarity and specificity is a respectable but imperfect two out of three. (See Appendix A: Methods, Criteria, and Grading Metric.)