SCIENCE

Montana

GRADE	SCORES		TOTAL SCORE
F	Content and Rigor	1/7	1/10
	Clarity and Specificity	0/3	

REPORT CARD

Content & Rigor	**1.3**
Scientific Inquiry & Methodology	2
Physical Science	1
Physics	0
Chemistry	0
Earth & Space Science	2
Life Science	3
Clarity & Specificity	**0.0**

Average numerical evaluations

Overview

Montana's science content is a thin amalgam of wooly commands and vague expectations. Oases of real information appear, but it's difficult to see how educators could tease more than a few drops of knowledge from the larger mirage.

Organization of the Standards

The standards are divided first into six broad strands (called "standards"). For each, the *Framework* provides "benchmarks" for fourth, eighth, and twelfth grades. These benchmarks are designed to be "check points along the K-12 continuum to assess student progress towards meeting the standards."

In a companion document, the state provides "Essential Learning Expectations for Science" (ELEs) for grades K-12. The ELEs communicate "the necessary content, context, and thinking/reasoning skills students must comprehend and apply along the learning continuum." The ELEs are presented grade by grade for Kindergarten through fifth grade, then in two grade bands: 6-8 and 9-12. Within the grade band covering 9-12, some standards are marked as tenth-grade expectations.

Content and Rigor

The Montana documents are permeated with vague if high-sounding generalities that are of little or no use in setting up a course of study. Although bits of well-developed content appear, these are stranded by poor or nonexistent follow-up and an overall failure to build on knowledge through the advancing grades.

Scientific Inquiry and Methodology

Across all grade levels and bands, the standards addressing scientific inquiry and methodology are vacuous. For instance, in fourth grade, students are expected to recognize that "knowledge is gained through questioning and observations," an empty observation grounded in no real science content. Also in fourth grade, students are asked to "list and discuss environmental problems and concerns." In eighth grade, they are expected to "investigate occupations that use science." To what end, we're never told. Likewise, we are never informed as to what makes science "a human endeavor," but eighth graders are somehow supposed to know.

Document(s) Reviewed

- *Montana K-12 Science Content Standards Framework*. 2006. Accessed from: http://www.opi.mt.gov/pdf/Standards/10ContStds-Science.pdf
- *Montana Essential Learning Expectations for Science*. 2009. Accessed from: http://opi.mt.gov/pdf/standards/09ScienceELE.pdf

One of the six content standards directs students to "understand historical developments in science and technology," but the benchmarks and ELEs within that standard are riddled with errors. For instance, historians and scientists alike will find it puzzling to read that James Hutton discovered the "naturalness of change theory"—a meaningless statement—and that Steno "recognized the importance of rock layers." Important for what, one wonders, as there is no mention of his priority in stating explicitly the basic stratigraphic principle that sedimentary layers form horizontally, the later ones on top of the earlier ones.

Like a number of other states, Montana tries to integrate the experiences of its indigenous peoples into its science standards. And as is too often the case, it never becomes clear how this integration is supposed to aid or develop student understanding of the process and content of science. For example, while first graders may enjoy discussing "Montana American Indians' explanations of the natural world," there is no guidance as to how this would function in the science classroom or build the students' scientific sophistication. The interest in indigenous experiences continues throughout the curriculum and leads to enigmatic expectations, such as, "Define and discuss what constitutes a community, a culture, and a society" (grade 4), or "Identify occupations that use science including Montana American Indians" (grade 4). Both are simplistic and banal, and the latter is poorly written to boot.

Physical Science/High School Physics/High School Chemistry

Some essential physical science content is covered thoroughly and at the appropriate level of rigor. For instance, the concept of gas is introduced in third grade; the distinction among solids, liquids, and gases is emphasized in fourth grade. Energy is introduced in third grade as "the ability to cause change." Refraction and reflection of light are introduced as early as first grade. And basic chemical concepts such as elements, compounds, and mixtures are introduced in fifth grade.

Unfortunately, omissions and errors also plague the standards. For instance, changes of state, introduced in first grade, are confusingly subsumed under the coverage of "energy." Many essential chemical concepts are also missing entirely, including chemical bonding (beyond mere mention), the ideal gas law, acid-base and redox reactions, stoichiometry or the mole concept, and solution chemistry. In fact, a scan of the entire document reveals the word "solution" only in the context of solving environmental problems.

Prerequisite content needed for high school chemistry is inadequate. The entire eighth-grade coverage of chemical topics is contained in the two woefully inadequate benchmarks:

1. **Classify, describe, and manipulate the physical models of matter in terms of: elements and compounds, pure substances and mixtures, atoms, and molecules.**
   a. **Classify matter as atoms, molecules, elements, compounds, pure substances, or mixtures.**
   b. **Identify common element and compounds by their symbol and chemical formula.**
   c. **Create and manipulate simple models of common elements and compounds.**
   d. **Identify the relationship between atoms, molecules, elements, compounds, pure substances, and mixtures.**
2. **Examine, describe, compare, and classify objects and substances based on common physical properties and simple chemical properties. (grade 8)**

An unfortunate by-product of this compression is the stuffing of such very important but diverse concepts of atom, element, and substances into a single, undifferentiated list. And the state never indicates what, precisely, the student is to know about each.

There are also outright errors, including the following:

> **Explain the relationship between changes in thermal energy and states of matter (e.g., increase/decrease of thermal energy = change in state).**
>
> **Recognize that temperature measures the average kinetic energy of particles in a substance. (grade 8)**

There is a failure here to make the fundamental distinction between kinetic and potential energy, let alone apply them to the kinetic theory.

The standards contain no specific coverage of high school physics or chemistry courses. Rather, there is a hodgepodge of physical science material in high school, much of it noted as tenth-grade expectations. The level of sophistication expected varies wildly from item to item, with no real system to their organization. For example,

> **Explain how the molecular geometry of a molecule (e.g., water) affects polarity and cohesive/adhesive properties. (grade 10)**

That's a pretty sophisticated task, rendered impossible by the fact that the standards neither ask students to be able to draw

Lewis dot structures for simple molecules nor use these dot structures to predict molecular geometry.

There is much throwing-around of high-sounding phrases that are so general as to be useless. One example is this twelfth-grade requirement:

> **Identify, measure, calculate, and analyze relationships associated with matter and energy transfer or transformations, and the associated conservation of mass. (grade 12)**

One might just as usefully (and more succinctly) condense the entire standard into the statement: "Think about scientific stuff."

Earth and Space Science

The coverage of earth and space science is equally poor and the standards just as vague. We are subjected to such vapidities as, "Compare and contrast the characteristics of Earth's natural features" (grade 4), or "Model and explain the internal structure of the earth and describe the formation and composition of earth's external features in terms of the rock cycle and plate tectonics and constructive and destructive forces" (grade 8).

Life Science

In the *Framework*, the word "evolution" and its variants appear only in four places. And the definition given in the glossary at the end is this:

> **Evolution – A process of change that explains why what is seen today is different from what existed in the past; it includes changes in the galaxies, stars, solar system, Earth, and life on earth. Biological evolution is any genetic and resulting phenotypic change in groups of organisms from generation to generation.**

This definition is far too sketchy to be of any pedagogical use. The term "natural selection" appears only once in the *Framework*, and only in a twelfth-grade benchmark. While it does appear more frequently (eight times) in the *Essential Learning Expectations* document, that coverage is primarily presented through tenth-grade expectations and is woefully inadequate. For instance, students are introduced to fossils in fourth grade, and these are explicitly linked to "past life"—the standards never make it clear that evolution is the unifying principle of the life sciences.

To make matters worse, we see hints of creationism in the use of the term "scientific theory," which appears *only* in the context of such subjects as cosmology and the fossil record. Students are instructed, for example, to "explain scientific theories about how fossils are used as evidence of changes over time" (grade 12) but not to explain scientific theories about how the periodic table predicts chemical similarities.

Pussyfooting around evolution is not the only weakness in the life science standards. Critical content is also missing. For instance, the documents contain no mention of physiology—no muscles, nerves, digestion, nothing. The most we get are the following standards from fourth grade and high school, respectively:

> **Identify that animals have systems for certain functions; explain the relationship between basic animal systems and their functions. (grade 4)**
>
> **Compare and contrast major animal phyla. (grade 10)**
>
> **Compare and contrast body systems between major animal phyla. (grade 10)**

The content here falls seriously short of a decent basis for a K-12 science education. With only glimmers of adequacy, the result is an average score of one out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

Montana's science standards are as poorly written as they are ambiguous. Typos and misspellings are rampant. Many statements are garbled. Sentences run on, seemingly at their own will. The order of presentation is inconsistent and at times illogical. And there is vagueness throughout. To give just one example:

> **Describe how scientific inquiry has produced much knowledge about the world and a variety of contributions toward understanding events and phenomenon [*sic*] within the universe. (grade 4)**

The Montana standards are among the poorest we have evaluated—they earn a zero out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)