SCIENCE

Colorado

GRADE	SCORES		TOTAL SCORE
D	Content and Rigor	2/7	3/10
	Clarity and Specificity	1/3	

REPORT CARD

Content & Rigor	**2.3**
Scientific Inquiry & Methodology	7
Physical Science	3
Physics	0
Chemistry	0
Earth & Space Science	1
Life Science	3
Clarity & Specificity	**0.8**

Average numerical evaluations

Overview

The Colorado standards begin with a mistranslation of renowned French mathematician Henri Poincaré's famous aphorism: "On fait la science avec des faits, comme une maison avec des pierres, mais une accumulation de faits n'est pas plus une science qu'un tas de pierres n'est une maison." A reasonable translation reads like this: "Science is made of facts, [just] as a house is made with stones, but an accumulation of facts is no more a science than a pile of stones is a house." The standards writers, however, came up with this:

> **Science is facts; just as houses are made of stone, so is science made of facts; but a pile of stones is not a house, and a collection of facts is not necessarily science.**

Alas, the muddled translation portends a confused and misguided presentation of content that at times "is not necessarily science" at all.

Organization of the Standards

Colorado's *Academic Standards* document first divides the standards into three strands: life science, physical science, and earth and space science. For each strand, the state provides a set of three or four "prepared graduation competencies," which explain broadly what students must know and be able to do upon graduation. Finally, grade-level expectations are presented from pre-Kindergarten through eighth grade. Only one set of standards is provided for high school.

Each of the grade-level expectations is coupled with a corresponding set of "evidence outcomes" as well as "21st century skills and readiness competencies," defined by inquiry questions, relevance and application, and nature of science.

The organization of Colorado's science standards is confusing in its hierarchy. The document *begins* by presenting the high school expectations, regressing back, grade by grade, to those of pre-Kindergarten. The tight, systemic structure of science is instantly compromised by this choice, as more complex concepts are unable to build upon earlier and more basic concepts in the standards.

Document(s) Reviewed

- *Colorado Academic Standards: Science*. Adopted December 10, 2009. Accessed from: http://www.cde.state.co.us/cdeassess/UAS/AdoptedAcademicStandards/Science_Standards_Adopted_12.10.09.pdf
- *Colorado Science Standards and Expanded Benchmarks*. 2005. Accessed from: http://www.cde.state.co.us/cdesped/download/pdf/Expanded_Benchmarks_Science.pdf

Content and Rigor

The material presented suffers from a serious lack of clarity, depth, and sufficient content. The standards have a frustrating tendency to string together numerous properties without explanation.

The grade-level expectations from pre-Kindergarten through seventh grade are quite low, lacking sufficient rigor throughout. In these grades, students are exposed to only one narrow subject each year, making any judgment of progress through grade levels impossible. Then, in eighth grade, exactly when students should be *specializing* in one of the sciences each year, the scope of the standards becomes much broader. It's hard to imagine how Colorado students will ever study essential scientific content at the appropriate level of depth and rigor with this confused and illogical presentation.

Scientific Inquiry and Methodology

This area stands out as the only one that is well covered. In the "Overview of Changes," the writers note that "the largest change to the science standards is acknowledging that scientific inquiry, science process skills, and content cannot be taught separately." Consistent with this statement, these standards focus solely on three disciplinary strands (life, physical, and earth sciences). "Scientific investigations" and "nature of science," both strands found in the previous iteration of Colorado's standards, have been subsumed into these three disciplinary strands.

Inquiry and process-skills material is now interwoven with disciplinary content, so that each conceptual expectation has associated nature-of-science competencies. For example, the eighth-grade physical science standard that asks students to "distinguish between physical and chemical changes, noting that mass is conserved during any change" is linked with the twenty-first-century (inquiry) skill "share experimental data, and respectfully discuss conflicting results emulating the practice of scientists." Overall, the inquiry material is clearly integrated with the conceptual, and historical/ethical matters receive some coverage.

Physical Science/High School Physics/ High School Chemistry

The physical science standards are generally weak, with a few bright spots appearing in the early grades. For starters, in first grade, students are asked: "What do all liquids have in common? What are some differences they can have and still be considered liquids? What do all solids have in common? What are some differences they can have and still be considered solids?" These inquiry questions provide a clear and grade-appropriate introduction to solids and liquids.

But such standards are the exception. More typically, we have such bewilderments as this, in eighth grade: "Identify and calculate the direction and magnitude of forces that act on an object, and explain the results in the object's change of motion." The implication here is that the eighth grader has completed studies of kinematics and dynamics, so that he or she can calculate the effects of force on the motion of an object. Of course the standards have not provided this critical prerequisite content, so the exercise is pointless.

Sixth graders are instructed to "develop an evidence-based scientific explanation of the atomic model as the foundation for all chemistry." Go to it, kids!

Chemistry is presented unsystematically and confusingly throughout the grades. In high school, for example, students are required to "predict and calculate the amount of products produced in a chemical reaction based on the amount of reactants," but the mole concept, essential to this exercise, has never been introduced. And there seems to be no material for high school physics.

Finally, too many standards are plagued by infelicities and plain errors. Some of the worst include: "Classify objects based on chemical properties (the ability of something to react) (e.g., ...vinegar's ability to react with vinegar)." Or this: "Describe transformation of forms of energy in terms of motion (e.g., fast, slow)," which means nothing at all. Or perhaps most distressingly, "Understand that a change in force will cause a change in speed an[d]/or direction of the object." This is the classical error of Aristotle—velocity is proportional to force—that Galileo went to so much trouble to demonstrate and supersede!

Earth and Space Science

A student who wants to learn about the structure of Earth will get little help here. The term "crust" appears exactly once, in sixth grade: "Use a computer simulation for Earth's changing crust." And there is nary a mention of either the mantle or the core.

The rock cycle appears once, in third grade, in the garbled phrase, "Earth's materials can be broken down and/or combined into different materials such as rocks, minerals, rock cycle, formation of soil, and sand—some of which are usable resources for human activity."

Sadly, these examples are the rule, rather than the exception, making the standards for earth and space science woefully inadequate.

Life Science

What aspects of life science will be covered in Colorado classrooms is a mystery. One searches the document in vain for any mention of the following basic terms: Mendel, mitosis, meiosis, mitochondrion, nucleus, prokaryote/eukaryote, and gamete.

The level of difficulty of the material presented varies wildly. At one extreme, students in high school are expected to study the energy involved in cell-membrane transport; the relevant data are, in fact, highly sophisticated, but there is not a hint as to how students would come to understand these data sufficiently to offer such interpretations. Kindergartners are supposed to compare and contrast data and question their peers about the evidence used in developing their ideas. Even preschoolers are supposed to predict, explain, and infer patterns based on observations.

At the other extreme, we have such trivialities as these: "Agriculture is of great importance to humans. For example, most food comes from agriculture" (grades 9-12). The creationist ploy of inviting students to study "strengths and weaknesses" of well-established biological knowledge seems to have sneaked into the Colorado standards through the back door. Students must "critically evaluate models used to represent deoxyribonucleic acid (DNA) and genes; identify strengths and weaknesses of these models for representing complex natural phenomena" (grade 8).

But as all practicing biologists know, there are no weaknesses in DNA models to discuss. Another example: "Critically evaluate models for photosynthesis and cellular respiration, and identify their strengths and weaknesses" (grades 9-12). Here again, the weaknesses are a figment of an untrained imagination.

Despite Poincaré's warning, the Colorado standards writers have passed off a pile of stones as a house. If not for the inquiry standards, the house would surely collapse. With them, the Centennial State earns a meager average score of two out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Colorado standards are as confusing as they are devoid of critical content. For starters, the backward organization of the standards makes it very hard to follow the development of a scientific idea as the student learns the simplest aspects as a child and progresses in sophistication as he moves on toward adulthood.

The writing is also repetitious and awkward—and at times ungrammatical. Some of the material is simply baffling. Stellar evolution is touched on in eighth grade in a garble: "How is the life cycle of a star such as the Sun similar to the cycle of life on Earth?" How, indeed! Absent any specific information about what, precisely, the state expects students to know and be able to do here, this standard is virtually meaningless.

And here's a honey of a quotation: "Analyze and interpret data on homeostatic mechanisms using direct and indirect evidence to develop and support claims about the effectiveness of feedback loops to maintain homeostasis" (grades 9-12). What that means, who really can say?

If these blunders were merely sour notes in an otherwise harmonious performance, it might be possible to overlook them. But they are set against a totality of information that suffers from a serious lack of clarity, depth, and sufficient content, and the standards therefore earn a one out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)