SCIENCE

Minnesota

GRADE	SCORES		TOTAL SCORE
C	Content and Rigor	4/7	5/10
	Clarity and Specificity	1/3	

REPORT CARD

Content & Rigor	**4.3**
Scientific Inquiry & Methodology	5
Physical Science	3
Physics	2
Chemistry	4
Earth & Space Science	6
Life Science	6
Clarity & Specificity	**1.0**

Average numerical evaluations

Overview

The Minnesota science standards are like the frustrating student who does excellent work two days a week but shoddy work on the other three. When the standards are "on," they are cogent and challenging. But too often they are marred by vague, incorrect, or grade-inappropriate material, or are missing key content entirely.

Organization of the Standards

Minnesota's standards are first divided into four strands: nature of science and engineering, physical science, earth and space science, and life science. Each strand is then divided into three or four unique sub-strands, each of which is further divided into two to four standards. For instance, there are two "standards" in the first physical science sub-strand:

> **STRAND 2: PHYSICAL SCIENCE**
>
> ***Substrand 1: Matter***
>
> **Standard 1. Properties and structure of matter.**
>
> **Standard 2. Changes in matter.**

Finally, grade-specific benchmarks are provided for all grades, K-8.

The high school standards are organized similarly, except that only a single set of benchmarks is provided for the 9-12 grade band.

In addition to the standards for grades 9-12, the state provides course-specific standards for high school chemistry and physics. (High school biology is subsumed under the "life science" strand for grades 9-12.)

Content and Rigor

The unevenness of the Minnesota science standards is evident both within and across subject areas. The treatment of life science and earth and space science is excellent, while that of physical science, and physics in particular, is mediocre or worse. Many of the problems stem from a failure to develop grade-appropriate expectations and to build on those expectations over time. As a result, although examples of

Document(s) Reviewed

- *Minnesota Academic Standards in Science K-12*. 2009. Accessed from: http://education.state.mn.us/mdeprod/idcplg?IdcService=GET_FILE&dDocName=005263&RevisionSelectionMethod=latestReleased&Rendition=primary

rigorous content abound, they often seem out of place or unachievable.

Scientific Inquiry and Methodology

The Minnesota standards for scientific inquiry and methodology are included in the "nature of science and engineering" strand, and the standards are generally thorough. For example, first graders are expected to support their claims with observations. Then at the third-grade level, students must be able to question the evidence others provide. At the high school level, this appropriately develops into an expectation for students to be cognizant of the effects of bias, the implications of their assumptions, and professional norms and ethics.

There are some drawbacks, however. Some standards are vague to the point of meaninglessness. For instance, third-grade students are to "understand that everybody can use evidence to learn about the natural world, identify patterns in nature, and develop tools." But surely there is more to scientific inquiry, even at that grade level, than this pious generality.

Though a minor issue, the standards are occasionally marred by an inappropriate focus on local beliefs. Fifth graders, for example, are told that science is "influenced by local traditions and beliefs," a truism that is a poor substitute for the reality that the scientific process aims to negate and overcome such influences in its pursuit of universal knowledge and understanding. The fascination with local traditions extends into high school, where students are asked to consider how "Native American understanding of ecology" has contributed to scientific ideas. No guidance is given as to what may be involved here, nor are any examples provided. The tendency to blur the distinction between scientific and traditional wisdom is not helpful to the students' development of a clear understanding of science.

Physical Science

The physical science standards are barely passable. While some important content is covered, much is missing—or slighted—and the overall impression is of disorganization and a superficial understanding of the subject matter on the part of the writers.

Conservation of mass is among the few topics that are reasonably well covered:

> **Differentiate between kinetic and potential energy and analyze situations where kinetic energy is converted to potential energy and vice versa. (grade 6)**

Unfortunately, such flashes of competence are rare.

Sometimes a disconnect emerges between the content introduced in a standard and the example set forth in the accompanying benchmark. Take, for example, the following from fourth grade:

> **Energy can be transformed within a system or transferred to other systems or the environment.**
>
> - **Demonstrate how an electric current can produce a magnetic force. (grade 4)**

Both statements are true, but the benchmark has nothing to do with the standard.

Other standards simply set unrealistic expectations. Students in sixth grade are, for example, asked to:

> **Use wave properties of light to explain reflection, refraction, and the color spectrum. (grade 6)**

That's a tall order for middle school students, and it doesn't help that it involves several quite diverse explanations involving the law of reflection, Snell's law, and the phenomena of dispersion (for prisms) or diffraction (for diffraction gratings), together with the physiology of color perception.

Occasionally, the standards require mastery of prerequisite content that is never included in previous grades. For example:

> **Explain and calculate the acceleration of an object subjected to a set of forces in one dimension ($F=ma$). (grades 9-12)**

But the student who has had no exposure to kinematics (specifically, the meaning and mathematical manipulation of acceleration) will be able to make nothing of this statement, for kinematics is treated nowhere in K-8 physical science prior to high school, and only very poorly even in high school physics (more on this in the high school physics section below).

Other standards are simply wrong, such as:

> **Glass conducts heat well, but is a poor conductor of electricity. (grade 4)**

No, glass is a poor conductor of heat. Indeed, very few materials conduct electricity poorly and heat well. Persons who are not aware of this property of solids ought not to be writing physical science standards.

High School Physics

The high school physics standards are marred by illogical organization. As noted above, prior to high school there is no discussion of kinematics in one dimension, let alone two. Yet high school physics students are expected to:

> **Use vectors and free-body diagrams to describe force, position, velocity and acceleration of objects in two-dimensional space. (high school physics)**

Then, immediately afterward, students are asked to:

> **Apply Newton's three laws of motion to calculate and analyze the effect of forces and momentum on motion. (high school physics)**

How does this relate to the item immediately preceding? What are we to make of the mention of momentum? And what follows in the next few items is pure chaos. Unfortunately, this typifies the entire treatment of high school physics.

High School Chemistry

The high school chemistry standards are marginally stronger than those for physics, especially the standards covering stoichiometry and solutions. Mathematical calculations, a central component to a rigorous high school chemistry course, are brought to the fore, notably in the standards on percent composition and empirical and molecular formulas. Moles, molar mass, balanced-equation relationships, and molarity are just a few of the topics described by fairly well-written content standards.

The handling of other topics—including chemical bonding, acids/bases, carbon chemistry, and the periodic table—is much weaker. For these, students are expected to understand concepts for which essential prior knowledge has not been specified. For example, students are asked to "relate the properties of acids and bases to the ions they contain and predict the products of an acid/base reaction." But there has been no discussion about ions or properties of ionic solutions—or even expected vocabulary words like "neutralization" or "titration."

No standard asks students to know the kinetic molecular theory itself, but still they are asked to use the theory to explain the "behavior of gases and the relationship among temperature, pressure, volume and the number of particles." This statement—the only standard about gases—is asking about the ideal gas law, but doesn't name the law or use its mathematical expression ($pV = nRT$). Further, the appropriate "moles of gas" is avoided, substituted for "number of particles."

Earth and Space Science

The Minnesota earth and space science standards are reasonably comprehensive, covering the water cycle, mineral properties, fossils, and natural resources. The basic structure of the solar system is also well covered, beginning in third grade with the following:

> **Recognize that the Earth is one of several planets that orbit the sun, and that the moon orbits the Earth. (grade 3)**

This is nicely expanded in eighth grade and in high school, with standards like this one:

> **Recognize that the sun is a medium-sized star, one of billions of stars in the Milky Way galaxy, and the closest star to Earth. (grade 8)**

> **Use the predictable motions of the Earth around its own axis and around the sun, and of the moon around the Earth, to explain day length, the phases of the moon, and eclipses. (grade 8)**

> **Describe how the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. (grades 9-12)**

A few things are missing, including detail on the workings of earthquakes and volcanoes. And some important content, which could and should be handled in elementary or early middle school, is not introduced until late middle school or high school. For instance, while plate tectonics is well treated, it is not introduced until eighth grade. In addition, while earlier grades do see mention of climate and weather, the distinctions among and origins of sedimentary, metamorphic, and igneous rock are deferred until eighth grade.

Other topics, such as cosmology, push the level of rigor too far:

> **Explain how evidence, including the Doppler shift of light from distant stars and cosmic background radiation, is used to understand the composition, early history, and expansion of the universe. (grades 9-12)**

That is a very big order for a single standard, and will surely overwhelm even the well-prepared high school student.

Life Science

Important life science content is presented quite minimally, but the flow and logic are such as to convey an understanding of the concepts rather than coming across as a list of topics to check off. The inclusion of examples from Kindergarten through eighth grade helps to further explain what students should know and be able to do.

Microbial infections and vaccination—subjects too often omitted from life science standards in Kindergarten through eighth grade—are tackled in eighth grade; their coverage is apt and well done. But while photosynthesis is mentioned in seventh grade, it lacks detail; in addition, there is no mention of respiration. (Both topics, however, are well-covered in high school.)

Similarly, seventh-grade students are asked to:

> **Recognize that cells contain genes and that each gene carries a single unit of information that either alone, or with other genes, determines the inherited traits of an organism. (grade 7)**

Yet there is no indication of what genes are or what they do, nor any mention of the proteins that are specified in the genetic code. Fortunately, these topics are covered in depth in high school.

In general, the high school standards are thorough and rigorous, with many outside-the-usual topics covered, like a continuation of microbial topics and coverage of genetic testing. The high school evolution section is complete and well organized.

Given the equal measures of good and the bad, the Minnesota science standards average out to a middling four out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

For the most part, the presentation of Minnesota's standards is clear—but specificity sometimes suffers. With respect to the latter, the main weakness lies in the physical sciences and the all-too-common mismatches between the standards and the examples given (some of which are described above).

A tendency toward needlessly befuddling language is another failing, particularly when straightforward mathematical concepts are at hand. Consider this demand in the chemistry material:

> **Use the kinetic molecular theory to explain the behavior of gases and the relationship among temperature, pressure, volume, and number of particles. (high school chemistry)**

This expectation could be much more compactly presented as, "Manipulate the equation $pV = nRT$."

Similar fuzziness is evident in the science process offerings. A curriculum founded on these materials would be a hodgepodge that fails to convey a sense of system to the student. Indeed, it would be an invitation to science by memorization. As such, the Minnesota standards earn themselves a one out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)