SCIENCE

Michigan

GRADE C

SCORES

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

TOTAL SCORE 6/10

REPORT CARD

Content & Rigor	**3.8**
Scientific Inquiry & Methodology	2
Physical Science	3
Physics	1
Chemistry	7
Earth & Space Science	5
Life Science	5
Clarity & Specificity	**1.8**

Average numerical evaluations

Document(s) Reviewed

- *Science Grade Level Content Expectations (v.1.09)*. 2009. Accessed from: http://www.michigan.gov/documents/mde/Complete_Science_GLCE_12-12-07_218314_7.pdf
- *Michigan Merit Curriculum, Science*. 2009. Accessed from: http://www.michigan.gov/mde/0,1607,7-140-38924_41644_42814---,00.html

Overview

The quality of Michigan's science standards varies greatly. Depending on grade level and subject matter, they range from thorough and rigorous to error-riddled and illogical. Of particular concern is that much content that is prerequisite for high school content is missing entirely from the K-8 standards.

The inconsistency leaves little confidence that students will graduate from high school having mastered the essential science content.

Organization of the Standards

The Michigan science standards are divided first into four "disciplines," or strands: scientific process, physical science, life science, and earth science. Each strand is further subdivided into three or four sub-strands. Then, grade-specific standards are provided for all grades, K-7.

The high school standards are presented for four courses: biology, earth science, chemistry, and physics. The state assumes that these content expectations will be covered in grades 8-11, with districts setting their own twelfth-grade standards. Each course is divided into strands. Biology, for example, splits into the following: organization and development of living systems, interdependence of living systems and the environment, genetics, and evolution and biodiversity. High school expectations are then identified as either "prerequisites" (what students are expected to know upon entering high school), "essential knowledge" (what graduates are expected to know, regardless of what courses they take in high school), "core knowledge" (what graduates who have completed a discipline-specific course are expected to know), and "recommended knowledge" (knowledge that is desirable as preparation for more advanced study in the discipline, but not required for graduation credit). How or where students who do not take a particular course will acquire the "essential knowledge" is unclear.

Content and Rigor

A common wisecrack about Michigan is that if you don't like the weather, wait a few minutes. The state's science standards seem to have embraced such variability as a guiding principle—and not to their advantage. Some disciplines are strong, even excellent (see chemistry), while others are weak, even disastrous (see physics). And even within a given subject, the rigor is inconsistent; the standards for Kindergarten through seventh grade are typically weaker than the high school content.

Scientific Inquiry and Methodology

The Michigan standards for scientific inquiry and methodology are vague to the point of near uselessness. While they include the usual process skills that students are expected to master in most states (e.g., "develop research strategies and skills for information gathering and problem solving" [grades K-7]), they rarely link these abstract goals to the content that students would need to learn to demonstrate mastery. For example, first graders are expected to "make careful and purposeful observations in order to raise questions, investigate, and make meaning of their findings." That's a lofty but empty requirement, grounded in no substantive content. In third grade, students are asked to describe "how people have contributed to science throughout history and across cultures," and by fifth grade, they are to explain "how science and technology have advanced because of the contributions of many people throughout history and across cultures." Surely, the history of science can be used in a more profitable and focused manner to illustrate how science is—and has been—practiced. The problem continues into high school, where, for example, the goal of analyzing "how science and society interact from a historical, political, economic, or social perspective" is presented with no guidance.

Nor is there much consistency or development of content from grade to grade. For example, second-grade teachers are told that experiences in the classroom should "inspire a sense of wonder and enthusiasm," and Kindergarten teachers are asked to exploit their students' "natural curiosity" for a subject that is of "high interest." Yet after fourth grade, no further mention is made of these elevated (if nebulous) goals.

Similarly, no mention is made from Kindergarten through seventh grade of important concepts such as hypothesis, law, or theory. Yet in high school, students are expected to "describe the distinctions between scientific theories, laws, hypotheses, and observations," something that could certainly occur sooner.

Physical Science

The development of physical science is often chaotic and illogical. Standards appear as a mixed bag of loosely related concepts, some of them poorly or incorrectly stated. The order of materials is scattered and the depth fluctuates wildly.

For example, a sub-strand appearing in third, fourth, sixth, and seventh grades asks students to:

> **Develop an understanding that there are many forms of energy (such as heat, light, sound, and electrical) and that energy is transferable by convection, conduction, or radiation. Understand energy can be in motion, called kinetic; or it can be stored, called potential. Develop an understanding that as temperature increases, more energy is added to a system. Understand nuclear reactions in the sun produce light and heat for the Earth. (grades 3, 4, 6, and 7)**

Here, four entirely distinct concepts are jammed together into a single statement.

Another unfortunate fourth-grade standard asks that students:

> **Measure the weight (spring scale) and mass (balances in grams or kilograms) of objects. (grade 4)**

The implication here is that a pan balance, unlike a spring scale, measures mass directly. It does not; it measures mass by comparing the weights of two samples, one of known mass. There are ways of measuring mass directly (e.g., the oscillating system used to measure the mass of astronauts in orbit) but this is not one.

Other standards are simply wrong. For instance:

> **Demonstrate that non-magnetic objects are affected by the strength of the magnet and the distance away from the magnet. (grade 4)**

Nonmagnetic objects are unaffected by magnets.

High School Physics

At the high school level, in antithesis to chemistry (see below), the treatment of physics becomes a confused mess. Too many standards are so broad as to be instructionally meaningless. Take, for example, the following:

> **Distinguish between rotation and revolution and describe and contrast the two speeds of an object like the Earth. (high school physics)**

What speeds? Is the intent to compare angular speeds (which doesn't make much sense here) or the rotational speed of some part of the earth with something else?

Other standards simply fail to introduce critical content adequately, such as:

> **Calculate force, masses, or distance, given any three of these quantities, by applying the Law of Universal Gravitation, given the value of G. (high school physics)**

Given all three quantities, what is to be calculated?

In places, the content information is muddled and misleading. For instance, students are asked to "explain how energy is conserved in common systems," but an example that follows is "mechanical energy in a collision"—a poor choice, as mechanical energy generally is not conserved in collisions.

The physics standards for the most part avoid the use of mathematical expressions at the cost of introducing confusion. Heat, temperature, and efficiency are unfortunately shoehorned into a single and optional standard.

High School Chemistry

In the early years, chemistry fares little better than physical science. From Kindergarten through seventh grade, the standards repeat the same topics over and over, year after year, with only minimal increase in depth or rigor. Their stated goal is to help students get ready to become scientists and deep thinkers, but one wonders how that will happen when they see such banal subjects as "properties of materials" repeated from grade to grade at the expense of more interesting content and more rigorous and grade-appropriate vocabulary.

Fortunately for Michigan pupils, the high school chemistry standards are generally well written and cover the critical content that students must learn as part of a rigorous, college-preparatory chemistry course.

A few topics are incomplete or missing, such as molarity, percentage of solution by mass or volume, and factors affecting solution formation. The ideal gas law is cited in three standards but never made explicit; certainly the simple equation $pV = nRT$ never appears. But overall, the high school standards are exceptional.

Earth and Space Science

The Michigan earth and space science standards start out weakly; much critical content is omitted from Kindergarten through seventh grade. In fact, while the high school standards list a number of "prerequisites" that students should have learned in earlier grades, many of these are either missing in Kindergarten through seventh grade, or not covered at the level of depth required for the high school content. For example, the high school standards require knowledge of stars and galaxies, but there is no mention of either prior to high school. Similarly, the evidence for the theory of plate tectonics is given as prerequisite to the high school standards, but the Kindergarten through seventh-grade standards do not address this interesting content.

Other topics are glossed over or excluded entirely. For instance, there is some mention of the solar system and planetary motion in fifth grade, but the coverage is insufficient at best. There is vague mention of mineral properties in third grade, but the identification by properties is missing (though this is also listed as a prerequisite for high school). Different types of rocks are referenced in sixth grade, but the rock cycle is neglected.

At the high school level, the *Michigan Merit Curriculum* standards are spectacular in breadth and depth, and often beautifully written. The histories of the universe and solar system are well treated, as are relative and absolute dating techniques. Volcanism is also well covered, as shown by the following illustrative example:

> **Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes. (high school earth science)**

There is much more to praise at the high school level, but the lack of coordination throughout the high school material and the weak support for that material in prior grades causes some concern.

Life Science

Much important life science content is either absent altogether or glossed over from Kindergarten through seventh grade. Evolution, for example, is treated inconsistently and incompletely. Survival, adaptation, and populations are all mentioned, but the standards contain nothing about natural selection or deep history (the distant past of the human species). The word evolution is never used. Fossils are mentioned in fifth grade, but only in passing.

In addition, errors frequently creep in. For instance, a seventh-grade standard asks that students:

> **Examine how through cell division, cells can become specialized for specific functions. (grade 7)**

In fact, that specialization occurs via differential gene expression, not cell division.

Happily, the high school standards are far better, containing excellent content that is systematically and explicitly laid out. The evolution unit is thorough and well done, with references in the contexts of ecosystems, genetics, molecular biology, biodiversity, and taxonomy, as well as a section whose primary subject is evolution.

That said, there are some gaps. For instance, while there is thorough coverage at the high school level of the scales of cells and subcellular systems, and of the scale of ecosystems, organ systems and physiology are not well treated.

A few errors also appear in high school. In biology, for example, students are required to:

> **Recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP. (high school biology)**

In fact, the important bonds in ATP are specific and unusual.

We are puzzled as to how the quality of treatment of several sciences could be so variable. The standards manage an average score of four out of seven for content and rigor, but that average masks a deeply uneven presentation of science. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Michigan standards are occasionally clear and specific, but much material is too garbled, poorly written, or illogically developed to drive a coherent science curriculum. For instance, in seventh grade, a standard explains:

> **Reflection and social implications are the application of the students' new knowledge and affects their decision making and their perception of the effect humans, scientific discovery, and technology have on society and the natural world. (grade 7)**

This statement, in addition to being grammatically untamed, is meaningless.

More troubling are the instances when the standards reveal a frustrating lack of logical flow. Consider this chain in the physics section (though the problem pervades the standards):

> **Gravitation is a universal attractive force that a mass exerts on every other mass. The strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. (high school physics)**

But the following instructions to "predict" or "calculate" cannot be accomplished without the quantitative form of Newton's law of gravitation, $F = GMm/r^2$.

> **Explain earth-moon interactions (orbital motion) in terms of forces. (high school physics)**

Any real "explanation" requires quantitative application of the law above, together with Newton's second law of motion, $F = ma$, which is implied but never made explicit in a preceding standard.

> **Predict how the gravitational force between objects changes when the distance between them changes. (high school physics)**

This is, of course, a vague verbal expression of one aspect of the law of gravitation. Logically, it comes prior to the other items, and so it ought to be stated before them. And the problems persist. How a teacher could be expected to make order out of this chaos is unfathomable.

The deeply uneven quality of the Michigan science standards suggests a failure to subject the document to a final, unified edit by persons who combine scientific expertise with an ability to set forth essential knowledge in a cogent, logical, and precise way. It also earns Michigan an average score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)