SCIENCE

Maryland

GRADE B

SCORES
Content and Rigor **5/7**
Clarity and Specificity **2/3**

TOTAL SCORE 7/10

REPORT CARD

Content & Rigor	**5.0**
Scientific Inquiry & Methodology	5
Physical Science	6
Physics	3
Chemistry	5
Earth & Space Science	6
Life Science	5
Clarity & Specificity	**1.6**

Average numerical evaluations

Document(s) Reviewed

- *Maryland Standards: State Curriculum.* 2008. Accessed from: http://mdk12.org/instruction/curriculum/science/index.html
- *Maryland Core Learning Goals: Science.* 2003. Accessed from: http://mdk12.org/instruction/curriculum/science/clg_toolkit.html

Overview

The Maryland science standards for grades preK-8 are generally clear and rigorous. The high school standards are weaker, alarmingly so in certain areas. However, the combination gives reason for confidence that students in the Old Line State will graduate having learned the essential science content they need to be college- and career-ready.

Organization of the Standards

Maryland's preK-8 science standards are divided by grade and then into six common strands: skills and processes, earth/space, life, chemistry, physics, and environmental science. Under each strand is a series of topics and, for each topic, one or more "indicators" are provided. Grade-specific objectives (or standards) are then provided for each indicator. Finally, the state has linked publicly released assessment questions to a number of the objectives at each grade level.

At the high school level, "core learning goals" are provided for four courses instead of by grade: physics, earth/space science, chemistry, and environmental science. The standards for these courses are organized similarly to the preK-8 standards, with two exceptions. First, there are only two strands per course—a skills and process strand, and the designated content. Second, because these courses are not assessed by the state, no assessment questions are provided.

In addition to the core learning goals, Maryland provides draft curriculum standards for high school biology that focus on two strands: skills and processes, and life sciences. (These standards have not been formally adopted as of November 2011, but are already widely used by school districts across the state.) Each strand is divided into expectations, for which one or more "indicators" are provided. In addition, the state defines "assessment limits" (topics to be assessed) and objectives for each biology indicator.

Content and Rigor

The elementary and middle school materials furnish a fine basis for curriculum development, generally covering the appropriate content and building on it with increasing complexity through the grades. (In fact, they occasionally expect too much, even for stern critics.) The same cannot be said for high school, however. Although not terminally weak, the content in the upper grades often falls short of the mark, typically by glossing over or omitting critical content.

Scientific Inquiry and Methodology

For each grade or course, the Maryland standards for scientific inquiry and methodology are outlined under a series of four to seven topics in the "skills and processes" strand. While these process standards are generally clear, they suffer from two significant shortcomings. First, they are repetitive, often closely duplicating standards across grade levels and making it nearly impossible to tell what progress is expected of students from grade to grade. Second, beyond the now-popular piety that science has been done by "different kinds of people, in different cultures, at different times," there is virtually no coverage of the historical development of scientific ideas.

Physical Science

The physical science material covers virtually all of the essential content. Thermometers are introduced in Kindergarten, and uniform, accelerated, and periodic motion in fifth grade. Forms of energy are introduced in a clear way in eighth grade. At the same time, work is properly defined in eighth grade, as demonstrated by the following:

> **Identify the relationship between the amount of energy transferred (work) to the product of the applied force and the distance moved in the direction of that force. (grade 8)**

In first grade, we read: "Make a list of possible advantages and disadvantages of differences of individuals in a population of organisms." This exercise provides a good preparation for later inquiry in depth. And it is a delight to read that Maryland asks Kindergartners to "explain that there must be a cause for changes in the motion of an object," with the following:

> **Observe and describe the ways in which a variety of objects' motion can be changed.**
>
> - **Speed up from a stand still**
> - **Slow down to a stop**
> - **Go faster**
> - **Go slower**
> - **No change**
> - **Change direction**
>
> **Based on observations, identify what caused the changes in an object's motion.**
>
> - **Push**
> - **Pull (Kindergarten)**

This explication is clear and entirely comprehensible for children of this age.

Similarly, in appropriately plain terminology for the grade level, we see: the zeroth law of thermodynamics introduced in third grade; "provide evidence that supports the idea that our solar system is sun-centered" in fifth grade; and Kepler's third law in eighth grade.

The good in the document is not unalloyed, however. Excessive repetition from grade to grade is particularly frustrating. For example, the international system of units (SI units) for area, volume, length, and weight in newtons are introduced in third grade and then repeated in fourth and fifth grades. The basic properties of solids, liquids, and gases are also repeated year after year.

At times, the standards ask students to undertake investigations that are impossible to execute. In one example, eighth graders are told to "formulate an explanation for the different characteristics and behaviors of solids, liquids, and gases using an analysis of the data gathered on the motion and arrangement of atoms and molecules." Although we suspect that students will see materials based on this statement in a much simplified form, the wording certainly makes it sound like a task for a university course in chemical thermodynamics.

High School Physics

The high school physics standards are brief but reasonably comprehensive. However, some restrictions are puzzling. Many subjects that lend themselves readily to quantitative discussion are explicitly limited to qualitative or semi-quantitative study. Among these are resolution of vectors (collinear and perpendicular only), projectile motion, and Coulomb's law. This numbers-light presentation runs contrary to the expectations of the traditional high school physics course, in which students are expected to use quantitative methods, including the simple trigonometry required to deal with two-dimensional vectors in any orientation.

In the treatment of thermodynamics, the term "irreversibility" is misused. And in spite of explicit emphasis on practical applications, heat engines are ignored. Finally, the order in which waves are discussed is illogical.

High School Chemistry

Much essential material is missing from chemistry, including equilibrium, gas laws and kinetic theory, quantitative stoichiometry, Lewis dot structures, and structural formulas and nomenclature for organic compounds. Molarity, which is defined as the number of moles of solute per liter of solution, is a quantitative measure by definition. Therefore, it is surprising that this fundamental concept should somehow be taught as "conceptual only" and not thoroughly explored. There is also no discussion of the connection between atomic electron transitions and spectral lines.

Of particular concern is the odd way in which each standard is followed by stringent "assessment limits." These seem designed to make sure the mediocre (or poorer) student doesn't get too low a grade. For instance, students are asked to "describe observed changes in pressure, volume, or temperature of a sample in terms of macroscopic changes and the behavior of particles." The assessment limits then indicate that students will only be assessed on their knowledge of:

- **Constant temperature (effect of pressure or volume change to sample of solid, liquid, or gas)**
- **Constant volume (effect of pressure or temperature change to sample of solid, liquid, or gas)**
- **Constant pressure (effect of temperature or volume change to sample of solid, liquid, or gas). (high school chemistry)**

The implication here is that the student is not to be required to use the full power of the ideal gas law, $pV = nRT$, explicit mention of which is somehow avoided in this rather vague group of standards.

Similarly, students are asked to "balance simple equations (not to include redox reactions)" as in:

- **Law of Conservation of Mass (apply to reactions to account for the same number of atoms of each type appearing in both the reactants and products)**
- **Coefficients (define; use to balance symbolic equations; explain meaning in symbolic equations; differentiate between the use and meaning of coefficients and subscripts). (high school chemistry)**

Admittedly, balancing redox reactions could get more difficult than balancing some other chemical equations, but simpler examples ought to be part of the high school chemistry curriculum. Ironically, the emphasis on "differentiat[ing] between the use and meaning of coefficients and subscripts" is negated in the document itself, with an utterly bewildering demand that students "use symbols to represent elements and polyatomic ions (limited to NH4+1,OH-1, NO3-1, NO2-1, ClO3-1,ClO2-1, HCO3-1, CO3-2, SO4-2, SO3-2, PO4-3, PO3-3; including diatomics – H2, O2, N2, Cl2, Br2, I2, F2; given periodic table and ion chart)."

Earth and Space Science

The earth and space science material is ambitious and generally excellent. In elementary school in particular, the content builds nicely through the grades. Observation of weather begins in pre-Kindergarten and is built upon systematically in grades four and six; similarly, the water cycle is introduced in first grade and there are good follow-ups in grades three, five, and eight. The basic properties of minerals and their place in the structure of rocks are well handled in fifth grade.

At the middle school level, the layered structure of Earth is introduced in sixth grade in some detail, though there is some minor confusion between the crust and the lithosphere.

Then in high school, the life cycles of stars receive adequate discussion, as does the important subject of relative and absolute dating. But the origin of the universe is touched upon only as a parenthetical remark, and plate tectonics is handled merely by a vocabulary list that covers a lot of ground with little explanation.

Unfortunately, while the high school earth and space science content is ambitious, it is also condensed to fewer than eight hundred words, meaning that some concepts—such as the solar cycle and the greenhouse effect—are mentioned without any attempt at exposition of the underlying mechanisms.

Although the effect is a concatenation of everything from the entire universe down to the details of solar activity, it does span plenty of ground.

Life Science

Many unrealistically broad and even impossible expectations populate the elementary and middle school standards for life science. Fourth graders are asked to "examine and compare fossils to one another and to living organisms as evidence that some individuals survive and reproduce." After using microscopes to "observe, describe, and compare single celled organisms," fifth graders are to "cite evidence from data gathered that supports the idea that most single celled organisms have needs similar to those of multicellular organisms." Such data are not evident from microscopy.

Evolution is introduced in eighth grade, but with a troubling feature: Five objectives are listed, but only the first two are to be assessed by the state. The remaining three objectives, which include coverage of natural selection, extinction, and evolution explaining species diversity, are purposely excluded from this assessment. In addition, the notion of common ancestry does not appear until high school, and even then no mention occurs of the deeply ancient nature of this ancestry. Human evolution is ignored.

The high school biology course—the only high school course for which a detailed curriculum is provided—provides a comprehensive and thorough list of topics covered, including in-depth biochemistry, cell biology and its relationship to organ systems and physiology, genetics, evolution, and ecology. Considerable attention has been given to such topics as the role of pH in maintaining life processes, enzyme kinetics, and the molecular biology of gene expression. A student mastering the material in this course would be excellently prepared for a college-level course, and indeed might perform well on an Advanced Placement test.

Overall, the Maryland science standards include much of the essential content that students must learn. As a result, they earn a solid five out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Maryland science standards are well organized and easy to follow. Unfortunately, the clarity of the presentation is often hampered by the vagueness of the standards themselves. Too often, standards are written so broadly that they fail to delineate what, precisely, students should know and be able to do. Take, for instance, this example from the "concepts of physics" core learning goals:

> **The student will relate thermodynamics to the balance of energy in a system. (high school physics)**

While grammatically correct, this sentence contains no meaningful information.

Other standards, while clear, lack the specificity they need to ensure that students learn the requisite content. For instance, in earth and space science, greenhouse gases are mentioned but there is no discussion of where they come from or how they affect Earth's climate. The document also contains a distracting density of typos, including the ever-popular "flourine" for fluorine.

As noted earlier, the standards are also repetitive, often closely duplicating standards across grade levels and making it nearly impossible to tell what progress is expected of students from grade to grade.

Taken together, these drawbacks earn Maryland a two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)