



SCIENCE

Vermont

GRADE SCORES TOTAL SCORE

C

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

5/10

REPORT CARD

Content & Rigor 2.8

Scientific Inquiry & Methodology	5
Physical Science	4
Physics	0
Chemistry	0
Earth & Space Science	3
Life Science	5

Clarity & Specificity 2.0

Average numerical evaluations

Overview

The Vermont standards are wildly variable in terms of quality, descending from the excellent treatment of life science to the hopeless mess that passes for high school physics. To make matters worse, the document is full of typos, incomprehensible statements, and empty chatter. If Vermont schools and teachers are in fact guided by these standards, it's impossible to imagine that students will graduate having learned the essential K-12 science content they need.

Organization of the Standards

Vermont has two main standards documents: *The Framework of Standards and Learning Opportunities*, and the *Grade Expectations* that support the *Framework*.

The first document covers “science, mathematics, and technology” in seven pages, a little more than two of which are devoted to science proper. The format of the whole is a table that divides standards into five strands: inquiry, experimentation, and theory; space, time, and matter; the living world; the universe, earth, and the environment; and design and technology. Each strand is then divided into sub-strands, for which a single standard is presented for each of three grade bands: preK-5, 6-8, and 9-12. These grade-band expectations are meant to explain “how the standard can be demonstrated.” For example, in grades 9-12, students are to:

Use Newton’s laws to explain quantitatively the effects of applied forces; observe, explain, and model object motion in a plane; qualitatively investigate conservation of momentum as it relates to collisions, and investigate the mechanics of rolling motion. (grades 9-12)

But in practice, the *Framework* serves as little more than an index to the far lengthier (122-page) *Grade Expectations*. While both documents were considered, the *Grade Expectations* was the focus of our review.

Like the *Framework*, the *Grade Expectations* document is divided first into strands, which are the same as those in the *Framework*. The strands are then divided into “enduring knowledge” themes, which are different than the *Framework’s* sub-strands, and finally, into “grade-cluster expectations” (GCEs). The GCEs are presented for six grade bands: preK-K, 1-2, 3-4, 5-6, 7-8, and 9-12. The introduction to the GCE document tells us:

Document(s) Reviewed

► *Vermont’s Framework of Standards and Learning Opportunities: Science*. Fall 2000. Accessed from: <http://education.vermont.gov/new/pdfdoc/pubs/framework.pdf>

► *Science Grade Expectations*. Summer 2004. Accessed from: http://education.vermont.gov/new/html/pgm_curriculum/science/gle.html

The GCEs specify two-grade cluster skills and content (preK-K, 1-2, 3-4, 5-6, 7-8, and proficient at high school, and advanced at high school). Two-grade clusters will:

- Provide more flexibility in creating local curriculum
- Allow for a broader time span in which developmental changes can be addressed
- Take into account local opportunities to learn

But this mention serves as the only reference to the proficient/advanced distinction, and it is unclear whether it applies to introductory versus more advanced courses (i.e., as an extension of the two-grade cluster system), or to regular and honors courses, or to some other entirely different concept.

Content and Rigor

The Vermont standards are maddeningly inconsistent. Although some disciplines contain reasonably rigorous material—life science in particular—other areas of science omit critical content, fail to develop important ideas, and include surprising errors.

Scientific Inquiry and Methodology

Within the scientific inquiry strand of Vermont’s GCEs, standards are grouped under six areas of “enduring knowledge”: scientific questioning, predicting and hypothesizing, designing experiments, conducting experiments, reporting data and analysis, and applying results.

The expectations for students are appropriate and clearly stated. For example, in grades 1-2, a reasonable explanation is defined as one that is based on observation; by grades 3-4, it is one which accurately reflects data, and so on. Important terms such as “explanation,” “prediction,” and “potential bias” (to give but three examples) are highlighted so as to draw attention to their importance. The concept of fair testing is clearly defined in grades 3-4.

There are a few drawbacks. For instance, the “examples/practice items” column is left empty throughout. Some examples linking the expectations with content would no doubt be useful to teachers. In addition, from seventh grade on, students are expected to answer the “So what?” question about their investigations, but little attention overall is paid to the larger social and historical aspects of science.

Physical Science/High School Physics/High School Chemistry

While the coverage of physics and physical science is generally abysmal, Vermont presents a few bright spots. Take, for example, the following standard, which provides a clear explanation of the ideal gas law:

- There exists a predictable relationship among the volume, temperature, and amount of a gas and the pressure the gas exerts.**
- For any specified amount of a gas, the pressure that the gas exerts will increase as the temperature increases or the volume of the gas decreases. The pressure that the gas exerts will decrease as the temperature decreases or the volume of the gas increases.**
- Gases exert pressure in all directions. (grades 7-8)**

A nice, qualitative introduction to Newton’s second law appears as well, but this is somewhat marred by a circular and misleading definition of acceleration:

Acceleration is a relationship between the force applied to a moving object and the mass of the object (Newton’s Second Law). (grades 7-8)

Under the “energy” heading, the progression of material is questionable. Specifically, heat energy is introduced at the preK-K level (with the distinction between heat energy and temperature made in grades 1-2), and electrical energy in grades 3-4, but no mention is made of the far more concrete mechanical energy. Incredibly, the term *kinetic energy* appears nowhere in this document! And, sadly, the common silliness of throwing around the term “entropy” is seen here, including an awful attempt to define it:

ENTROPY = heat/temperature e.g., such as from engines, electrical wires, hot-water tanks, our bodies, stereo systems.

Huh?

As a “science concept” repeated at several grade spans tells us, “Energy is required to transform the physical state of a substance from solid to liquid to gas, while conserving mass. Physical changes are reversible.” But this is plain wrong. The melting of butter, for instance, is a physical process but when the resulting liquid is cooled one does not get butter back again.

Or consider this hodgepodge, which requires students to demonstrate their understanding of the states of matter by:

Investigating the interactions between atoms or molecules within a system (e.g., hydrogen bonding, van der Waals forces, fluorescent lights, stars). (grades 7-8)

Why in the world would the standards single out two of the weakest interatomic forces—hydrogen bonding and van der Waals forces—and then jumble them together with fluorescent lights and stars? In neither of the latter two do those particular forces play a significant role, and in both of them a host of very complex interatomic interactions occur.

Such lapses are not the exception. The following is yet another risible “science concept”:

Chemical change is a transformation of matter that results from the interaction of the molecules in a substance and a new substance results (e.g., electrophoresis of water). (grades 7-8)

It would make a pretty exam question for the seventh and eighth graders to correct this statement!

The chemical content of physical science is no better than the physical part. Take, for example, the following expectation, which asks that students demonstrate their understanding of properties of matter by:

Writing formulae for compounds and developing models using electron structure (e.g., Lewis dot). (grades 9-12)

The first part is fine, and comprises a standard part of introduction to chemical principles. But what “models” are wanted in the second? The term Lewis dot [structure] implies bonding, molecular shape, and polarity. But that critical content is conspicuously absent.

The terms ionic and covalent bonds do not appear, nor does metallic bond. Hydrogen bonding is mentioned by name, but that’s all. There is no mention of chemical equilibrium, no mention of Le Châtelier’s principle, and no mention of quantum or Bohr atomic models.

Finally, nothing in the standards document is suitable for the conventional high school course in physics or chemistry—a major failing.

Earth and Space Science

Earth and space science fares somewhat better, but not much. Occasional flashes of detailed critical content appear, but overall, serious gaps persist. Significant in their absence are such important topics as rocks and minerals, the workings of volcanoes and earthquakes, the greenhouse effect, and the solar cycle.

Furthermore, while there is an attempt to build on content from grade to grade, sometimes the addition at each step is little more than trivial. Take, for example, the following standards for grades 3-8:

Students demonstrate their understanding of Processes and Change over Time within Earth Systems by...

- **Describing water as it changes into vapor in the air and reappears as a liquid when it is cooled. (grades 3-4)**
- **Diagramming, labeling, and explaining the process of the water cycle (e.g., evaporation, precipitation, runoff). (grades 5-6)**
- **Diagramming, labeling, and explaining the process of the water cycle (precipitation, evaporation, condensation, runoff, ground water, transpiration). (grades 7-8)**

This grade-to-grade “progress” is little more than reiteration of the same ideas in different words.

Worse still, some items are written so broadly that they present virtually no meaningful content whatsoever. Consider the following examples:

Identify and record patterns and forces that shape the earth (e.g., geological, atmospheric). (grades K-4)

Identify, record, and model evidence of change over time (e.g., earth’s history: biological, geological). (grades 5-8)

Explain the emergence of modern views of the universe (past, present, and future scientific theories). (grades 9-12)

In addition to being virtually useless to teachers and curriculum developers, we are bemused by the requirement that high school students explain cosmological views of the future as well as those of the past and the present.

Life Science

While life science suffers from some errors and omissions (discussed below), it generally receives the best content coverage of any of the sciences. Overall, the content and flow of this section is impressive. Clearly, the writers did not just download boilerplate from other sources. For example, in the first unit of fifth- and sixth-grade life science, cells are introduced by noting that they have the same survival needs as organisms and that they differentiate. Too often, this key point is not made, even in high school. There is also a good treatment of physiology in these grades, even introducing white blood cells, and a good unit on embryos.

All continues to go well at the high school level. We read, “All body cells have identical genetic information, but its expression may be very different from one cell to another due to the instructions given to different types of cells” (grades 9-12). There is a major unit on embryo development and a sophisticated consideration of human physiology and disease.

Evolution is treated adequately but far from thoroughly. In the beginning grades, we read of “things that no longer live on earth (woolly mammoth)” (grades 1-2). In seventh and eighth grades, there is a fairly minimal consideration of the concepts, but the core ideas are there. At the high school level, the core ideas are again there, but compared with, say, the in-depth coverage of physiology and genetics, the treatment is skeletal and confined to one box.

As mentioned above, the treatment of life science does present some errors. For instance, a preK-K standard begins with the following:

The human body is unique in its heredity, body systems, and development, and can be affected by the environment. (preK-K)

This is repeated in third and fourth grades. Yet the human body is NOT unique in its heredity, and while one of its body systems (the brain) has important (to us) unique features such as the capacity to learn symbolic language, the important point is that the human body is overwhelmingly like other mammals.

Reflecting its flashes of excellence amidst mediocrity, Vermont earns a three out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Vermont documents are marred by many typos and much tangled phraseology, and often the grade-to-grade development is inadequate. As noted above, the specificity of subject-matter treatment varies widely from subject to subject.

Logical and pedagogical inconsistencies abound. In physical science, what students learn in grades 5-6 is contradicted in grades 7-8:

All substances have a unique density that depends on the volume (amount of space) that the substance is packed into. (grades 5-6)

Changing the temperature of materials will change the density of the material. (grades 7-8)

In physics, motion and force are presented in two separate sections, in that order. But dynamics (including Newton’s second law) is subsumed under motion, which leads to confusion. It would have been much better to divide the subject the logical way, into kinematics and dynamics.

Taken together, the strengths marginally outweigh the weaknesses, earning Vermont an average score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)