SCIENCE

Utah

GRADE	SCORES		TOTAL SCORE
B	Content and Rigor	5/7	7/10
	Clarity and Specificity	2/3	

REPORT CARD

Content & Rigor	**4.8**
Scientific Inquiry & Methodology	5
Physical Science	4
Physics	4
Chemistry	5
Earth & Space Science	5
Life Science	6
Clarity & Specificity	**2.1**

Average numerical evaluations

Document(s) Reviewed

- *Utah Elementary Science Core Curriculum: K-2*. 2010. Accessed from: http://www.schools.utah.gov/CURR/main/Core-Curriculum/By-Subject/K-2ScienceCoreCurriculum.aspx
- *Utah Elementary Science Core Curriculum: 3-6*. March 2002. Accessed from: http://www.schools.utah.gov/CURR/main/Core-Curriculum/By-Subject/Scie3-6.aspx
- *Utah Secondary Science Core Curriculum: 7-8*. April 2003. Accessed from: http://www.schools.utah.gov/CURR/main/Core-Curriculum/By-Subject/Scie7-8.aspx
- *Utah Secondary Science Core Curriculum: 9-12*. April 2003. Accessed from: http://www.schools.utah.gov/CURR/main/Core-Curriculum/By-Subject/Scie9-12.aspx

Overview

The Utah standards do many things well; clear language and rigorous, grade-appropriate content predominate. Yet this generally solid effort is dogged by vague or incomplete statements, and some inaccurate or missing material.

Organization of the Standards

The Utah science standards are presented in four documents, each covering a different grade span: K-2, 3-6, 7-8, and 9-12. The standards for grades 3-12 were adopted between 2002 and 2003, along with a set of "integrated" K-2 standards, which lumped the science standards together with those for fine arts, social studies, health, and physical education. In 2010, Utah replaced the integrated K-2 standards with science-specific content standards.

The K-2 document stands apart from the rest. It divides material first into four "big ideas": the processes, communication, and nature of science; earth and space science; physical science; and life science. Each big idea is then divided into grade-specific objectives, which are then described by indicators.

The material for grades 3-8 is presented by grade, and the high school material is presented by course. The standards documents each begin with a description of six "intended learning outcomes" (ILO), common across all grades and courses, which describe the process outcomes that students should achieve. For instance, students will "manifest scientific attitudes and interests" or "use science process or thinking skills." Each of the six general ILOs is then followed by grade- or course-specific outcomes. Apart from the ILOs, expectations are divided into grade- and course-specific series of benchmarks, standards, objectives, and indicators.

Third grade focuses on relationships, motion, and cause and effect. Fourth grade examines Utah's natural history, and fifth grade looks at change and cause and effect. Sixth grade deals with scale and relative position. Grades seven and eight are integrated courses, while the high school standards are divided into earth systems, biology, chemistry, and physics.

Content and Rigor

The content that is covered in the Utah standards is generally thorough and scientifically accurate. Unfortunately, some critical content is missing, particularly in the higher grades, and excessive repetition undermines the overall effectiveness of the standards.

Scientific Inquiry and Methodology

The difference between the K-2 and 3-12 process standards is noteworthy. The former are strong—the objectives and indicators are clear and they are tied to specific content. In addition, the state offers guidance for combining process and content (as well as introducing themes from science, technology, and society). The only weak point is the reference to "ideas in science" and that "ideas are supported by reasons"—surely more precise language should be used even at these early grades.

Unfortunately, the standards for grades 3-12 are far weaker. For starters, the intended learning outcomes are vague to the point of meaninglessness. For instance, by the end of third grade, students will "demonstrate a sense of curiosity." Only a small handful of the ILOs are specific, and several seem out of place. For instance, by the end of fifth grade, students will "accept and use scientific evidence to help resolve ecological problems."

History gets a clear mention at the high school level—"relate the nature of science to the historical development of the theory of evolution"—but not at earlier grades.

Physical Science

Physical science presents a mixed picture. Magnets and magnetism are introduced relatively late, in fifth grade, with observations and activities that should be completed earlier. But laudably, electrostatic phenomena and circuit construction are introduced in tandem with them, which gives students an uncommonly early insight into the important complementarity of magnetism and electricity. Heat, optics, and sound are treated in a substantial and systematic way in sixth grade.

Yet the eighth-grade physical science material does not measure up. Take the following example:

> **Investigate the application of forces that act on objects, and the resulting motion.**
>
> **a. Calculate the mechanical advantage created by a lever.**
>
> **b. Engineer a device that uses levers or inclined planes to create a mechanical advantage.**
>
> **c. Engineer a device that uses friction to control the motion of an object.**
>
> **d. Design and build a complex machine capable of doing a specified task.**
>
> **e. Investigate the principles used to engineer changes in forces and motion. (grade 8)**

None of these examples gets at the objective, which really has to do with Newton's second law.

High School Physics

High school physics begins with an excellent development of kinematics and dynamics. For example, Newton's first law of motion is stated thus:

> **The motion of an object can be described by measurements of its position at different times. Velocity is a measure of the rate of change of position of an object. Acceleration is a measure of the rate of change of velocity of an object. This change in velocity may be a change in speed and/or direction. Motion is defined relative to the frame of reference from which it is observed. An object's state of motion will remain constant unless unbalanced forces act upon the object. This is Newton's first law of motion. (high school physics)**

Missing, unfortunately, are the quantitative statements essential to physics at this level. Likewise, Newton's law of gravitation and Coulomb's law are presented in a flurry of circumlocution instead of as two simple equations. Words are important, but at the high school level they cannot replace direct quantitative statements.

The physics standards section does not purport to be encyclopedic: "Not all possible physics topics are specified in the [standards]. Teachers may enhance their individual classes as they see opportunities to include more topics or more depth." Yet too many critical subjects are absent. Kinematics, dynamics, and energy conservation are well covered, and thermodynamics, electromagnetism, light, and sound get at least some attention. Totally absent, however, are planetary dynamics and Kepler's laws, modern physics (including significant products like transistors, lasers, and nuclear power generators), fluid flow, and kinetic theory.

In the material that is present, the level of expectation is often low. For instance, students are asked to "identify the relationship between the speed, wavelength, and frequency of a wave" (high school physics). A physics student ought to be able to do more than merely "identify" the relation $v = f\lambda$.

High School Chemistry

The chemistry curriculum lists six standards, each with its own objectives and indicators. Many of these are quite good and clearly written—as is the case with the standards dealing with both equilibrium and solutions. Still, many others are not. In particular, some important topics are either missing or incomplete.

Organic chemistry, for example, does not get even a mention. The elementary organic compound methane is given as an example in one of the objectives, but in a completely different context. Kinetic molecular theory and the gas law relationships (including the ideal gas law and molar volume) are missing completely. These are serious omissions.

In one objective, students are asked to describe the shape and polarity of water, ammonia, and methane molecules from a given model. But there is no mention of Lewis dot structures, molecular polarity is not defined, and limiting this topic to only these three molecules is setting the bar quite low.

Worse, there is no requirement that students be able to write and balance chemical equations. The requirement that students be able to "use a chemical equation to describe a simple chemical reaction" (high school chemistry) is not specific enough. Terms such as molar proportions and molar relationships are given, but the definition of mole is not.

Earth and Space Science

Earth and space science fares better, especially in elementary and middle school. Earth structure and history and cosmology are covered well. For example, here is what eighth graders learn about fossils:

> **Describe how rock and fossil evidence is used to infer Earth's history.**
>
> **a. Describe how the deposition of rock materials produces layering of sedimentary rocks over time.**
> **b. Identify the assumptions scientists make to determine relative ages of rock layers.**
> **c. Explain why some sedimentary rock layers may not always appear with youngest rock on top and older rocks below (i.e., folding, faulting).**
> **d. Research how fossils show evidence of the changing surface of the Earth.**
> **e. Propose why more recently deposited rock layers are more likely to contain fossils resembling existing species than older rock layers. (grade 8)**

Fourth graders receive an unusually precise introduction to weathering and erosion:

> **Distinguish between weathering (i.e., wearing down and breaking of rock surfaces) and erosion (i.e., the movement of materials). (grade 4)**

Unfortunately, some sections that begin strong lose rigor as they progress. High school earth systems begins with the following excellent expectations:

> **Compare the movement and results of movement along convergent, divergent, and transform plate boundaries. (high school earth systems science)**

> **Explain Alfred Wegener's continental drift hypothesis, his evidence, and why it was not accepted in his time. (high school earth systems science)**

But it then devolves into the vague:

> **Model the movement of materials within Earth. (high school earth systems science)**

> **Model the movement and interaction of plates. (high school earth systems science)**

Some content is missing—notably from the high school standards. Factors that determine climate, the study and measurement of earthquakes, and the mechanics of volcanoes are conspicuously missing. Despite a good treatment of the Big Bang theory and the evidence for it, the theoretical history of the solar system is not addressed.

Life Science

Life science starts out well in the primary grades but peters out in later years. The fourth-grade material on Utah's natural history is handled nicely. Heredity is introduced in fifth grade and microbes in sixth grade. But the seventh-grade material (where most middle school biology is commonly presented) is thin, and the standards addressing heredity do not progress much beyond the fifth-grade expectations. There is also some error: "Cite examples of organisms that reproduce sexually (e.g., rats, mosquitoes, salmon, sunflowers) and those that reproduce asexually (e.g., hydra, planaria, bacteria, fungi, cuttings from house plants)" (grade 7). But fungi reproduce sexually.

Fossils are well covered in fourth grade, and the related standards give the concept of deep time. Unfortunately, a classification unit in seventh grade is at the level of sophistication of elementary grades and avoids any mention of relatedness between organisms.

Evolution is handled well at all levels. Take, for example, this second-grade standard:

Some kinds of living things that once lived on earth have completely disappeared, although they were something like others that are alive today. (grade 2)

At the high school level, the treatment of evolution is even excellent:

Evolution is central to modern science's understanding of the living world. The basic idea of biological evolution is that Earth's present day species developed from earlier species. Evolutionary processes allow some species to survive with little or no change, some to die out altogether, and other species to change, giving rise to a greater diversity of species. … Cite evidence that supports biological evolution over time (e.g., geologic and fossil records, chemical mechanisms, DNA structural similarities, homologous and vestigial structures). (high school biology)

And there is more. A reference to the "Utah State Board of Education Position Statement on Teaching Evolution" unequivocally presents the scientific significance of biological evolution.[1]

Taken together, these strengths and drawbacks earn Utah a respectable average score of five out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Utah standards often lack specificity, especially in the physical sciences. There, standards are replete with bewildering and meaningless statements, and some outright errors. For example:

Investigate and measure the effects of increasing or decreasing the amount of energy in a physical or chemical change, and relate the kind of energy added to the motion of the particles. (grade 8)

Whatever does this mean? Or this:

Measure and graph the relationship between the states of water and changes in its temperature. (grade 8)

Similarly, when dealing with earth and space science, the document has a tendency to dance around ideas that ought to be more explicitly connected:

Relate the structure and composition of the solar system to the processes that exist in the universe.

a. Compare the elements formed in the big bang (hydrogen, helium) with elements formed through nuclear fusion in stars.

b. Relate the life cycle of stars of various masses to the relative mass of elements produced.

c. Explain the origin of the heavy elements on Earth (i.e., heavy elements were formed by fusion in ancient stars).

d. Present evidence that the process that formed Earth's heavy elements continues in stars today.

e. Compare the life cycle of the sun to the life cycle of other stars.

f. Relate the structure of the solar system to the forces acting upon it. (high school earth systems science)

A simple reference to the Hertzsprung-Russell diagram, the life cycle of supernovae, and a statement about stellar "generations" would help tremendously here.

Such complications, and the burden of excessive repetition throughout the standards, earn the Utah standards an average score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)

[1] See the "Utah State Board of Education Position Statement on Teaching Evolution" at http://www.schools.utah.gov/CURR/science/Secondary/Evolution-Position-Statement/EvolutionPositionStatement.aspx.