SCIENCE

Arkansas

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

REPORT CARD

Content & Rigor	**5.2**
Scientific Inquiry & Methodology	2
Physical Science	5
Physics	7
Chemistry	7
Earth & Space Science	3
Life Science	7
Clarity & Specificity	**2.0**

Average numerical evaluations

Overview

Arkansas presents a well-organized and generally sound set of science standards, with thorough and excellent treatment of most—though not all—disciplines. Curricula that are well aligned to this document ought to be solidly grounded and, provided they are staffed by scientifically competent teachers, classrooms of the Natural State could do a fine job of science education.

Organization of the Standards

Arkansas's K-8 standards are divided into four strands: nature of science, life science, physical science, and earth and space systems. Each strand is sub-divided into two or three "standards," covering broad notions such as "characteristics and processes of science" and "living systems: characteristics, structure, and function." The standards are further divided into subheadings, and finally into grade-level expectations.

At the high school level, the standards are presented similarly except that course-specific expectations, rather than grade-level expectations, are presented for anatomy and physiology, biology, chemistry, environmental science, physical science, and physics.

Content and Rigor

The Arkansas standards do many things well. For nearly every discipline (earth and space science and physical science excepted), they cover all of our critical points of content with sufficient rigor and at the appropriate grade level. The examples are explicit and generally spot-on, and concepts develop over advancing grade spans—both of which make it easy to trace the accumulating knowledge that students will obtain as they progress through the school system.

Scientific Inquiry and Methodology

The scientific inquiry and methodology standards, presented within the "nature of science" strand, are the worst of the bunch. Here, students are asked to "demonstrate and apply knowledge of the characteristics and processes of science using appropriate safety procedures, equipment, and technology." Unfortunately, the skills that they are to acquire in achieving this goal are aphoristic and hopelessly vague. For example,

Document(s) Reviewed

- *Arkansas K-8 Science Curriculum Framework*. Revised 2005. Accessed from: http://arkansased.org/educators/pdf/science_k-8_011006.pdf
- *Arkansas High School Science Curriculum Frameworks*. Revised 2005. Accessed from: http://arkansased.org/educators/curriculum/frameworks.html#science

students in fifth grade are asked to "summarize the characteristics of science." One hopes their instructors have a clear idea of what these "characteristics" are, because the standards give no indication.

Similarly content-free standards can be found throughout. Fourth graders are asked to "evaluate the quality and feasibility of an idea or project," with no hint as to how they might make such an evaluation. Fifth graders are expected to "make accurate observations," but it is only in sixth grade that they are expected to verify the accuracy of their observations. One must wonder how they knew in the previous grade that they were meeting their goals of accuracy. At the high school level, students "research historical and current events" in the content areas. But the standards give no indication of what events students are meant to investigate, or even to what end students should be doing such research.

Physical Science

The Arkansas physical science standards are generally strong, and most of the basic concepts are introduced at the proper grade level. Beginning in second grade, students make measurements in SI (standard *Système International d'Unités*, or International System of Units) with the range of measurements expanding systematically grade by grade. Force and motion are introduced in second grade. Force and direction, as well as force and mass, are introduced in fourth grade. Eighth graders receive a solid treatment of waves.

Arkansas's presentation of physical science is well constructed. Covered in the chemical section are kinetic theory, latent heats, the triple point, and Boyle's and Charles's laws (though not the ideal gas law). Kinematics and dynamics are developed systematically, using equations as necessary. Conservation of momentum is covered, and energy is addressed even more completely. As in the lower grades, the high school treatment of waves, including both sound and light, is clear.

The standards include an unusually complete discussion of some basic concepts of organic chemistry, including carbon-carbon bonds, allotropes, structural formulas, and types of compounds with biological functions.

High School Physics

The treatment of high school physics is excellent. The document perhaps goes overboard in expressing ideas in mathematical form; it would be better to have more explanatory text, as equations by themselves tend to be narrow in scope. But the physics standards cover pretty much what one would encounter in a college-level non-calculus physics course. Indeed, the physics standards read almost like an abridged textbook. The sequence is traditional and thorough: one-dimensional kinematics; one-dimensional dynamics; vector analysis; two-dimensional mechanics (including parabolic trajectories and motion under a central force); Newton's law of gravitation; work; the work-energy theorem; impulse and momentum; and collisions. Following this come equally thorough and correct treatments of fluid dynamics and thermodynamics, the latter including a proper, if brief, handling of Newton's second law and a discussion of heat engines. Simple harmonic motion is covered, followed by geometric optics; curiously, wave optics and waves in general are mentioned only in passing. Treated briefly but carefully are electrostatics and electromagnetism, with explicit mention of Faraday's law. Quantum phenomena are covered briefly as well.

High School Chemistry

The Arkansas chemistry standards are particularly strong; all of our content criteria—and much more—are thoroughly covered by the Arkansas standards. A number of topics are especially comprehensive. These include chemical bonding, stoichiometry, and organic chemistry. The treatment of gases is also extensive and doesn't shy away from calculations. It includes: relating kinetic theory to molecular motion, elastic collisions, temperature, and pressure; calculations of the effects of pressure, temperature, and volume on the number of moles of gas particles in chemical reactions; calculations with all the gas laws again connecting p, V, T, and moles of a gas (the names and formulas were given for the following laws: Avogadro's, Boyle's, Charles's, combined, Dalton's, Graham's, Gay-Lussac's, and the ideal gas law); and calculations of mass and gaseous volume relationships, based on the stoichiometry of balanced chemical equations.

Further adding to the high school chemistry material, Arkansas provides a five-page glossary of generally well-written terms. The definition for "base," for example, gave: "A substance which produces hydroxide ions in water solution ([A]rrhenius); a proton acceptor (Brønsted); an electron pair donor (Lewis)."

These glossary definitions further exemplify the depth and attention to detail found in the Natural State's chemistry standards. Whereas most states barely ask students to know that bases provide hydroxide ions in water (and don't give credit to Arrhenius), Arkansas students are required to know these more advanced concepts. The 2005 chemistry revision committee should be congratulated for producing such a comprehensive document.

Earth and Space Science

The K-8 earth and space science standards cover a good deal of content. Unfortunately, though the standards have adequate breadth, they often lack depth. For example, in third grade, students are asked to:

> **Describe the layers of Earth:**
>
> - **crust**
> - **mantle**
> - **inner core**
> - **outer core (grade 3)**

Unfortunately, this standard leaves far too much interpretation to the teacher or curriculum developer. Worse, the standard repeats, hardly changed, in sixth grade. This makes it unclear when and how the thickness of the crust and the relative average density of continental versus ocean crust, brittleness, and so forth are supposed to be taught. Unfortunately, the other standards are similarly vague.

The Arkansas standards do not include earth and space science standards in high school, although the environmental science document contains a rather brief section titled "physical dynamics." This section has only nineteen entries, many of which are quite broad. For example, students are asked to:

> **Describe the structure, origin, and evolution of the Earth's components:**
>
> - **atmosphere**
> - **biosphere**
> - **hydrosphere**
> - **lithosphere (high school environmental science)**

This, like the other eighteen standards, fails to delineate what, specifically, students need to know or be able to do, leaving the high school earth and space content rather sparse.

Life Science

The life science standards are well organized. Concepts are developed carefully through the grade levels and there is good balance among subjects.

Evolution is treated unflinchingly, which is a great step forward for Arkansas. While the concept of evolution is not explicitly presented as the central organizing principle of biology, the coverage begins with a study of fossils in fifth grade and receives appropriately progressive treatment from then on.

High school biology is also excellent. For example, students are asked to "analyze the meiotic maintenance of a constant chromosome number from one generation to the next." The standards for biochemistry, cell biology, and genetics are all impressive for their depth and rigor.

In addition, students are required to spend time on dissections. The standards mention several times, for example, that there will be a dissection of a poultry egg (presumably a chick embryo) in seventh grade. While this is a tricky dissection, the very idea of even *looking* at a chick embryo in seventh grade is a great one.

That said, there are occasionally some curious expectations. For instance, the standards require fifth graders to dissect both eyes and lungs—messy tissues that make this exercise impractical at this level.

Overall, the strengths of the Arkansas standards far outweigh the weaknesses and earn the Natural State a solid average score of five out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

The Arkansas standards are generally systematic and clearly presented. But there are notable lapses. As noted above, the inquiry and methodology guidelines are hopelessly vague. And too many standards fail to specify what, precisely, students should know and be able to do. For example, a fourth-grade physical science standard asks students to "investigate the relationship between force and direction." It's unclear how a nine- or ten-year-old would go about investigating such a relationship, nor what relationship he or she is expected to discover.

Similarly, in third grade, students are asked to "differentiate between magnets and non-magnets." Beyond saying "this is a magnet and this isn't," it's unclear what Arkansas is asking of its students.

Finally, a seventh-grade standard asks students to "compare and contrast Newton's three laws of motion," but it's not entirely clear why this is a useful exercise. Many other verbs would have made more sense; such as "describe," "explain," or even "use" (although this last is likely premature in seventh grade).

At least this silliness receives redemption in what immediately follows, when students are asked to:

> **Conduct investigations demonstrating Newton's first law of motion**
>
> **Demonstrate Newton's second law of motion**
>
> **Conduct investigations of Newton's third law of motion. (grade 7)**

These standards are clear and specific and their ordering is especially laudable, considering how many states compress all three of Newton's laws into a single sentence.

Finally, Arkansas would have done well to jettison—or at least overhaul—the glossary appended to the K-8 document. As it stands, it is risible. Here are some examples:

> **Absorption: When white light wave passes through a substance the energy of certain colors may be taken in by the substance and converted to a different form of energy.**

This is a mélange of fifth-grade syntax with eighth-grade understanding.

> **Chemical change: Any change where one or more of the original materials changes into other materials.**

These "other materials," we suppose, being chemically different from the original ones?

> **Transparent: The ability of light to pass through without refraction.**

Except, of course, for the 100 percent of transparent materials at whose surfaces light beams refract. (Course-specific glossaries in high school, however, fared better.)

Taken together, these strengths and weaknesses earn the Natural State an average score of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)