SCIENCE

Georgia

GRADE	SCORES		TOTAL SCORE
C	Content and Rigor	4/7	6/10
	Clarity and Specificity	2/3	

REPORT CARD

Content & Rigor	**4.2**
Scientific Inquiry & Methodology	5
Physical Science	4
Physics	2
Chemistry	3
Earth & Space Science	5
Life Science	6
Clarity & Specificity	**1.8**

Average numerical evaluations

Overview

The extraordinary unevenness of the Georgia standards reflects the disorganization of the parts. Some areas are strong and some adequate, while others lag badly. Although the end product is mediocre, better editing and a bit more attention to detail could significantly improve the standards.

Organization of the Standards

Georgia presents its science learning expectations by grade for K-8 and by course for high school. Content standards and "characteristics" (or inquiry) standards are presented for each grade and course. Grades K-5 each cover earth, life, and physical sciences. Sixth grade focuses exclusively on earth science, seventh grade on life science, and eighth grade on physical science.

At the high school level, the Georgia standards offer a bewilderingly large number of courses. In addition to the traditional biology, chemistry, and physics courses, there are astronomy, botany, earth systems, ecology, entomology, environmental science, epidemiology, forensic science, geology, human anatomy and physiology, meteorology, microbiology, oceanography, physical science, and zoology. As these courses fall outside the conventional, much broader core science curriculum, and as we have no idea when and how these myriad specialized courses are worked into students' learning plans, we have focused this review solely on the four core subjects.

The Peach State also presents a series of framework documents, one for each grade, K-8, and for physics, chemistry, biology, and physical science in high school. Within each of these documents is a strange mixture of classroom activities, lesson plans, common misconceptions, and key questions. The presentation within these documents is so sketchy, and the organization so chaotic, that a full evaluation is impossible, if not inappropriate. We therefore limit our discussion to the standards documents.

Content and Rigor

Georgia has produced a frustratingly spotty set of standards that range from excellent (life science) to pretty bad (physics and chemistry). When good, the material is well written, concrete, and thorough, with ambitious but not unreasonable expectations for what students ought to know, in both the lower and upper grades. Unfortunately,

Document(s) Reviewed

- *Georgia Science Standards*. 2004-2009. Accessed from: https://www.georgiastandards.org/standards/Pages/BrowseStandards/ScienceStandards.aspx such moments are not the norm. In too many instances, the material is sloppily presented, unfocused, or poorly supported.

Scientific Inquiry and Methodology

The Georgia standards contain good, clear statements on process. For example, in fifth grade: "Similar scientific investigations seldom produce exactly the same results, which may differ due to unexpected differences in what is being investigated, unrecognized differences in the methods or circumstances of the investigation, or observational uncertainties." Well put.

Physical Science

The physical science standards are decidedly mixed. Some content is covered with depth and rigor. For example, the first-grade handling of light, sound, and magnetism is quite good. The standards take note of the fact that magnetic force is not blocked by paper, for example. Second grade introduces energy, but never deals with the question (tricky at this level) of what energy is. In third grade, heat is introduced nicely, and magnetism (introduced two grades earlier) is expanded. The introduction in fourth grade of optics—including mirrors, lenses, and prisms—is excellent.

Two specific examples will suffice to show how very good the standards can be. In eighth grade:

> **Students will have the computation and estimation skills necessary for analyzing data and following scientific explanations.**
>
> **a. Analyze scientific data by using, interpreting, and comparing numbers in several equivalent forms, such as integers, fractions, decimals, and percents.**
>
> **b. Find the mean, median, and mode and use them to analyze a set of scientific data.**
>
> **c. Apply the metric system to scientific investigations that include metric to metric conversions (i.e., centimeters to meters).**
>
> **d. Decide what degree of precision is adequate, and round off appropriately.**
>
> **e. Address the relationship between accuracy and precision.**
>
> **f. Use ratios and proportions, including constant rates, in appropriate problems. (grade 8)**

And at the high school level:

> **Students will explore the nature of matter, its classifications, and its system for naming types of matter.**
>
> **a. Calculate density when given a means to determine a substance's mass and volume.**
>
> **b. Predict formulas for stable binary ionic compounds based on balance of charges.**
>
> **c. Use IUPAC nomenclature for transition between chemical names and chemical formulas of**
>
> - **binary ionic compounds (containing representative elements).**
> - **binary covalent compounds (i.e., carbon dioxide, carbon tetrachloride).**
>
> **d. Demonstrate the Law of Conservation of Matter in a chemical reaction.**
>
> **e. Apply the Law of Conservation of Matter by balancing the following types of chemical equations:**
>
> - **Synthesis**
> - **Decomposition**
> - **Single Replacement**
> - **Double Replacement. (high school physical science)**

Sadly, as often as they are this good, the standards fail to outline sufficiently the content that students need to learn. For instance, gravitation is introduced in Kindergarten, but in a way that is likely to confuse more than clarify. Specifically, students are asked to "observe and communicate effects of gravity on objects," and to:

> **Recognize that some things, such as airplanes and birds, are in the sky, but return to earth.**
>
> **Recognize that the sun, moon, and stars are in the sky, but don't come down.**
>
> **Explain why a book does not fall down if it is placed on a table, but will fall down if it is dropped. (Kindergarten)**

Is the Kindergartner to conclude that gravity affects books always, airplanes sometimes, but stars never? In the child's first encounter with a phenomenon, it is best to present the simple and obvious first, and then move on to the complications.

Then in fifth grade, students are presented with this statement: "In simple terms, a chemical change cannot be reversed and a physical change can." Clearly, however, neither part of this statement is true. The melting of butter is an irreversible physical change, while the chemical reaction $2Hg + O_2 \leftrightarrow 2HgO$ is readily reversible.

And here is the sum total of the eighth-grade coverage of mechanics:

> **Students will investigate relationship between force, mass, and the motion of objects.**
>
> **a. Determine the relationship between velocity and acceleration.**
>
> **b. Demonstrate the effect of balanced and unbalanced forces on an object in terms of gravity, inertia, and friction.**
>
> **c. Demonstrate the effect of simple machines (lever, inclined plane, pulley, wedge, screw, and wheel and axle) on work. (grade 8)**

High School Physics

The high school physics course is divided into five major concepts/skills: kinematics, energy and its transformations, electricity, magnetism, and wave properties. To the physicist's eye, this is a very strange—and illogical—division. Kinematics without dynamics is pointless; electricity and magnetism belong together (as indeed they are in Georgia's standards for the lower grades); and heat and thermodynamics are missing, as are optics and pretty much all of modern physics.

Getting down to detail, Newtonian dynamics is telescoped into a few words; nuclear fission and fusion are introduced without preparation, under an "energy" standard that *precedes* the standard containing the basics of the work-energy theorem, energy conservation, and the mere mention of potential energy. The rest is mere chaos, ending with a section devoted to relativity.

High School Chemistry

Only about a page and a half of the standards are dedicated to actual chemistry content; predictably, much essential content is missing. For instance, there is nothing on the important topic of gases. Nor is there anything about Lewis dot structures or how they can help predict the shape and polarity of molecules. The topic of chemical bonding is reduced to "compare and contrast types of chemical bonds (i.e., ionic, covalent)." Hydrogen bonding and metallic bonding are completely missing. Also missing is any mention of oxidation/reduction. The important topic of chemical equilibrium (and Le Châtelier's principle) is reduced to a meaningless standard asking students to "explain the role of Equilibrium in chemical reactions." There is no mention of carbon (organic) chemistry, and the periodic table section is inadequate. If basic topics like groups (chemical families), periods, metallic, nonmetallic, and metalloid regions, and so forth, are not taught in primary and middle school grades, then they need to be addressed in high school chemistry. (High school physical science contains some topics, like specific heat and conductivity of solutions, that should have been included in chemistry.)

Earth and Space Science

The earth and space standards taken alone (that is, ignoring the framework documents) are well written, reasonably ambitious, and complete. The standards for Kindergarten through eighth grade have some weaknesses in rocks and minerals and details of plate tectonics. The high school material is contained in a large collection of high school courses. Though none of the courses related to earth and space material addressed all our suggested content, each was well written and could lead to an interesting and serious semester course. It is not clear, however, which or how many students would take those courses.

Georgia offers some particularly nicely written entries, for instance:

> **Students will model the position and motion of the earth in the solar system and will explain the role of relative position and motion in determining sequence of the phases of the moon. (grade 4)**
>
> **Demonstrate the relative size and order from the sun of the planets in the solar system. (grade 4)**
>
> **Compare and contrast the Earth's crust, mantle, and core including temperature, density, and composition. (grade 6)**
>
> **Relate the Nature of Science to the progression of basic historical scientific models (geocentric, heliocentric) as they describe our solar system, and the Big Bang as it describes the formation of the universe. (grade 6)**

Each of these examples displays good knowledge of the subject and how students might demonstrate deep understanding. The entry on the layers of the solid earth calls out the specific properties of each layer that sixth graders should be able to understand. Modeling the geometry of moon phases is a great way to demonstrate an understanding of motions in the solar system. Relating the progression of historical ideas about important models is a sophisticated way to address the science behind current understandings.

Life Science

Unlike the other disciplines, the presentation of life science material is quite good, typified by the systematic treatment of evolution in middle school. It begins with a fine general statement in the benchmarks covering sixth through eighth grades:

> **During middle school, several lines of evidence are further developed. The fossil evidence can be expanded beyond extinctions and survivals to the notion of biological history. Sedimentation of rock can be brought in to show relative age. However, actual age, which requires an understanding of isotopic dating techniques, should wait until high school, when students learn about the structure of atoms. Breeding experiments can illustrate the heritability of traits and the effects of selection. (grades 6-8)**

Further, Georgia's standards are one of the few to discuss Darwin prior to the high school level:

> **Explain that physical characteristics of organisms have changed over successive generations (e.g., Darwin's finches and peppered moths of Manchester).**
>
> **Describe ways in which species on earth have evolved due to natural selection.**
>
> **Trace evidence that the fossil record found in sedimentary rock provides evidence for the long history of changing life forms. (grade 7)**

High school biology coverage is sound and generally complete, tackling organelles, mitosis and meiosis, Mendel's Law, and photosynthesis well (to name a few subjects). The standards' focus on the cell and molecular-level content offers thoughtful overviews and good specific examples. Unfortunately, the strong seventh-grade coverage of evolution is not carried along to high school, where coverage of evolution is missing such key concepts as DNA or the sequences of amino acids—though it does include coverage of molecular and anatomical evidence.

In the end, these peaks and valleys leave Georgia with a four out of seven for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

As is the case with the content and rigor of Georgia's standards, much inconsistency of quality is seen in terms of clarity and specificity. When they are good, the Georgia standards offer information accurately and in simple prose. We have cited several examples of this fine work above. But when they are bad, they produce brief and vapid expressions, as in: "Explain the role of equilibrium in chemical reactions" (high school chemistry). More detail is ardently desired, yet none is forthcoming.

In some places, the standards' brevity leaves the reader confused, as in the following example:

> **Measure and calculate the magnitude of frictional forces and Newton's three Laws of Motion. (high school physics)**

This is both an illogical combination and a mighty tall order to compress all of Newton's laws (e.g., all of dynamics) into half of a fourteen-word statement. The result, of course, is neither clear nor specific. And then there's this:

> **Determine the heat capacity of a substance using mass, specific heat, and temperature. (high school physical science)**

The intent, doubtless, was something like, "Calculate the *quantity of heat absorbed or given out* by an object when its mass, specific heat, and temperature *change* are known." But as written, the passage is not only confusing, it's simply wrong.

These issues taint the otherwise straightforward Georgia standards, resulting in a score for the Peach State of two out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)