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Astronomy in the K–8 Core Curriculum: A Survey of State Requirements Nationwide

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Abstract

We have compiled the K–8 core standards in astronomy for 48 states and the District of Columbia. Astronomy coverage in state curricula varies broadly from state to state, both in quantity and in content. Comparing these core standards between states and with the National Research Council (NRC) astronomy core standards gives interesting information for outreach professionals building curriculum materials for national distribution. Although the NRC standards provide a solid starting point for curriculum development, most states expand their astronomy coverage beyond the NRC topics.

1. INTRODUCTION

In 1996, the National Research Council (NRC) published the *National Science Core Standards* (NRC 1996), a potential starting point for the development of state core curricula in the sciences. The implementation of these core standards has varied from state to state, both in content and in timing, with individual states making decisions about not only what should be covered in K–12 education but also when students are prepared to tackle specific scientific concepts.

This state-to-state variation makes preparation of curriculum materials difficult for large organizations hoping to have national impact. These organizations often fall back to the NRC core standards to determine the intersection of their materials with the content goals of teachers. However, how the individual state core standards compare with the NRC standards is unclear. To find out, we have compiled the astronomy standards for most of the nation, searching the published state science standards for astronomy content.

We had several questions that wanted to answer:

- Are state core curricula similar to one another with respect to astronomy content?
- Are the same topics being taught at the same level in most states?
- How similar are the core concepts to those recommended by the National Research Council?

2. GATHERING DATA

2.1 State Core Standards

Data were gathered from the Web sites of individual state departments of education or equivalent (hereafter referred to generally as DoEd) between January 2006 and June 2006. We gathered data for 48 states and the District of Columbia (Iowa's standards are not published online, and Michigan's standards were undergoing revision). Shortly into the research, we decided to limit ourselves to grades K–8, leaving grades 9–12 for a later time.

In all cases, we assumed that the published online data from the states' DoEds were current. This may or may not be true, but because these standards often vary from year to year (consider the well-known case of Kansas), a "snapshot" of the state standards is probably the best one can do.

For the first 15 states, we kept a list of the topics covered and the grade level in which they were taught. This allowed us to build a matrix of topics versus state (see Table 1). Further states were added to this matrix. When necessary, new topic columns were added. In total, 45 astronomy topics of varying specificity are covered in grades K–8.

Table 1. Astronomy core standards across the nation. Each column contains the topic title and the grades in which it is taught for each state. For the readers' convenience, the total number of topics in each state is tabulated in the left-most row, and the number of states teaching each topic is tabulated in the bottom row. The Web sites from which this information was obtained are given in the appendix.

Click here to open Table 1 in Excel format.

2.2 National Content Standards

2.2.1 The NRC Core Curriculum Standards

The NRC standards are available online (http://newton.nap.edu/html/nses/) or in book form (NRC 1996). These standards are conveniently grouped, varying from general science standards (e.g., critical thinking, mathematical reasoning) to specific content standards (e.g., "the Earth goes around the Sun"). We limited ourselves to content standards, which compare most easily with the state standards. The NRC standards are divided into K–4 and 5–8 grades. For the reader's convenience, we reproduce the astronomy content of these standards here:

K–4
I) The Sun, Moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.

II) The Sun provides the light and heat necessary to maintain the temperature of the Earth.

III) Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The Moon moves across the sky on a daily basis much like the Sun. The observable shape of the Moon changes from day to day in a cycle that lasts about a month.

5–8
IV) The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the Solar System.

V) Most objects in the Solar System are in regular and predictable motion. Those motions explain such phenomena as the day, the year, the phases of the Moon, and eclipses.

VI) Gravity is the force that keeps planets in orbit around the Sun and governs the rest of the motion in the Solar System. Gravity alone holds us to the Earth's surface and explains the phenomena of the tides.

VII) The Sun is the major source of energy for phenomena on the Earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the Sun's energy hitting the surface due to the tilt of the Earth's rotation on its axis and the length of the day.

2.2.2 The AAAS Core Curriculum Benchmarks

Similarly, Project 2061 (a project of the American Association for the Advancement of Science [AAAS]) has derived "benchmarks" for science literacy. In general, benchmarks are more detailed than standards and can be thought of as "drilling down" into the content to a more detailed level. Here, for convenience, we list the astronomy-related benchmarks (Project 2061 1993) and, where possible, identify them with an NRC content standard, in parentheses.

K–2

- There are more stars in the sky than anyone can easily count, but they are not scattered evenly, and they are not all the same in brightness or color. (I)
- The Sun can be seen only in the daytime, but the Moon can be seen sometimes at night and sometimes during the day. The Sun, Moon, and stars all appear to move slowly across the sky. (III)
- The Moon looks a little different every day but looks the same again about every four weeks. (III)
- The Sun warms the land, air, and water. (II)

3–5

- The patterns of stars in the sky stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons. (III)
- Telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.
- Planets change their positions against the background of stars (V, although not explicitly)

- The Earth is one of several planets that orbit the Sun, and the Moon orbits the Earth. (IV)
- Stars are like the Sun, some being smaller and some larger, but so far away that they look like points of light. (IV, implicitly, "The Sun, an average star. . . ")
- Like all planets and stars, the Earth is approximately spherical in shape. The rotation of the Earth on its axis every 24 hours produces the night-and-day cycle. To people on earth, this turning of the planet makes it seem as though the Sun, Moon, planets and stars are orbiting the earth once a day. (V)

6–8

- The Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night. The universe contains many billions of galaxies, and each galaxy contains many billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot.
- The Sun is many thousands of times closer to the Earth than any other star. Light from the Sun takes a few minutes to reach the Earth, but light from the next nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of years. Some distant galaxies are so far away that their light takes several billion years to reach the Earth. People on Earth, therefore, see them as they were that long ago in the past.
- Nine planets of very different sizes, composition, and surface features move around the Sun in nearly circular orbits. Some planets have a great variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The Earth is orbited by one moon, many artificial satellites, and debris. (IV)
- Large numbers of chunks of rock orbit the Sun. Some of those that the Earth meets in its yearly orbit around the Sun glow and disintegrate from friction as they plunge through the atmosphere—and sometimes impact the ground. Other chunks of rocks mixed with ice have long off-center orbits that carry them close to the Sun, where the Sun's radiation (of light and particles) boils off frozen material from their surfaces and pushes it into a long, illuminated tail. (IV)
- We live on a relatively small planet, the third from the Sun in the only system of planets definitely known to exist (although other similar systems may be discovered in the universe). (IV, although this benchmark obviously requires modification to accommodate the discovery of extrasolar planets.)
- Everything on or anywhere near the Earth is pulled toward the Earth's center by gravitational force. (VI)
- Because the Earth turns daily on an axis that is tilted relative to the plane of the Earth's yearly orbit around the Sun, sunlight falls more intensely on different parts of the Earth during the year. The difference in heating of the Earth's surface produces the planet's seasons and weather patterns. (III or V)
- The Moon's orbit around the Earth once in about 28 days changes what part of the Moon is lighted by the Sun and how much of that part can be seen from Earth—the phases of the Moon. (V)
- The Sun's gravitational pull holds the Earth and other planets in their orbits, just as the planet's gravitational pull keeps their moons in orbits around them. (VI)

In this study, we concentrate on comparing the state core standards with the NRC core standards for three reasons. First, nearly all states had published curricula at the core standard level of detail. Second, although benchmarks exist in most states, the level of detail involved makes a comparison between different sets of curricula prohibitively difficult. Third, the NRC core standards and the AAAS benchmarks are quite congruent, with only 3 of the 19 benchmarks not covered in the NRC core standards.

The exceptions can be summarized as covering telescopes, the size of the universe, and the structure of the universe.

3. GENERALIZING THE STATES' RESULTS

The number of astronomy standards taught in a given state varies from a low of 7 in Maryland to a high of 38 in Missouri. The average number is 19. Figure 1 shows the distribution of the number of topics taught. The popularity of topics is given in Table 2. The six most popular topics are taught in more than 45 states. These topics are probably not a surprise, covering primarily the Earth-Moon-Sun system and the Solar System.

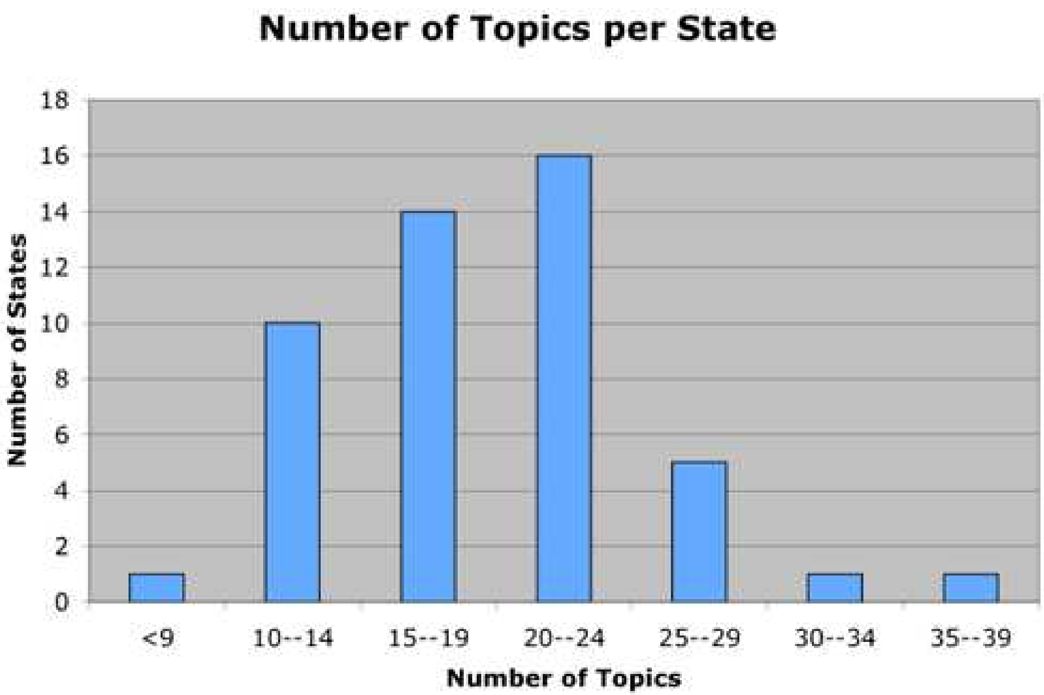

Figure 1. The number of states with a given number of topics in their core curriculum. The average number is 19, the maximum is 38, and the minimum is 7.

Table 2. The Popularity of Astronomy Topics in the States' Cores

N	Topics
N>=45	Earth's orbital properties; **Sun properties; Moon properties; Earth tilt/seasons; Moon phases; Planets/Solar System**
40<=N<=44	**Inner/Outer planet characteristics**
35<=N<=39	**Sun, Moon, stars appear to move east to west; Objects in the sky; Rotation; Revolution**
30<=N<=34	**Sun "moves" in the sky; Earth's position in the Solar System; Gravitational attraction/Newton's laws**
25<=N<=29	**Solar/lunar eclipse; Moon/tides;** Asteroids/comets/meteors
20<=N<=24	Star cycle/properties; Star maps/constellations; Galaxies
15<=N<=19	Organization of known universe; Earth/Moon are round; Distances in space; Space exploration/telescopes/live in space
10<=N<=14	Solar System location in galaxy; H-R diagram; Fusion/stellar energy source; Earth/Sun distance/solstice; Origin and evolution of universe and Solar System; Technology from space exploration; Current technology/careers; Evidence for big bang
5<=N<=9	Distance of stars/brightness; Spectroscopy of stars/elements; Universe motion/expansion/Doppler effect; Types of 'scopes (X-ray, IR); History of astronomy/geocentric versus heliocentric models; Light year; Deep sky objects
N<=4	North star; Culture related to objects in the night sky; Aurorae; Earth-asteroid history; Time from sky/Big Dipper clock; Radiating/reflecting bodies

Note: N, in the first column, is the number of states teaching the topics listed in the second column. Bolded topics are those that are similar to the topics in the NRC core curriculum.

A geographical comparison of the number of astronomy topics per state (see Figure 2) shows no correlation with political (i.e., "red-blue") maps. This may indicate that the local politics of the electorate has little influence on the amount of astronomy taught in a given state. Nor is there an obvious correlation with latitude, population density, good observing weather, or dark skies.

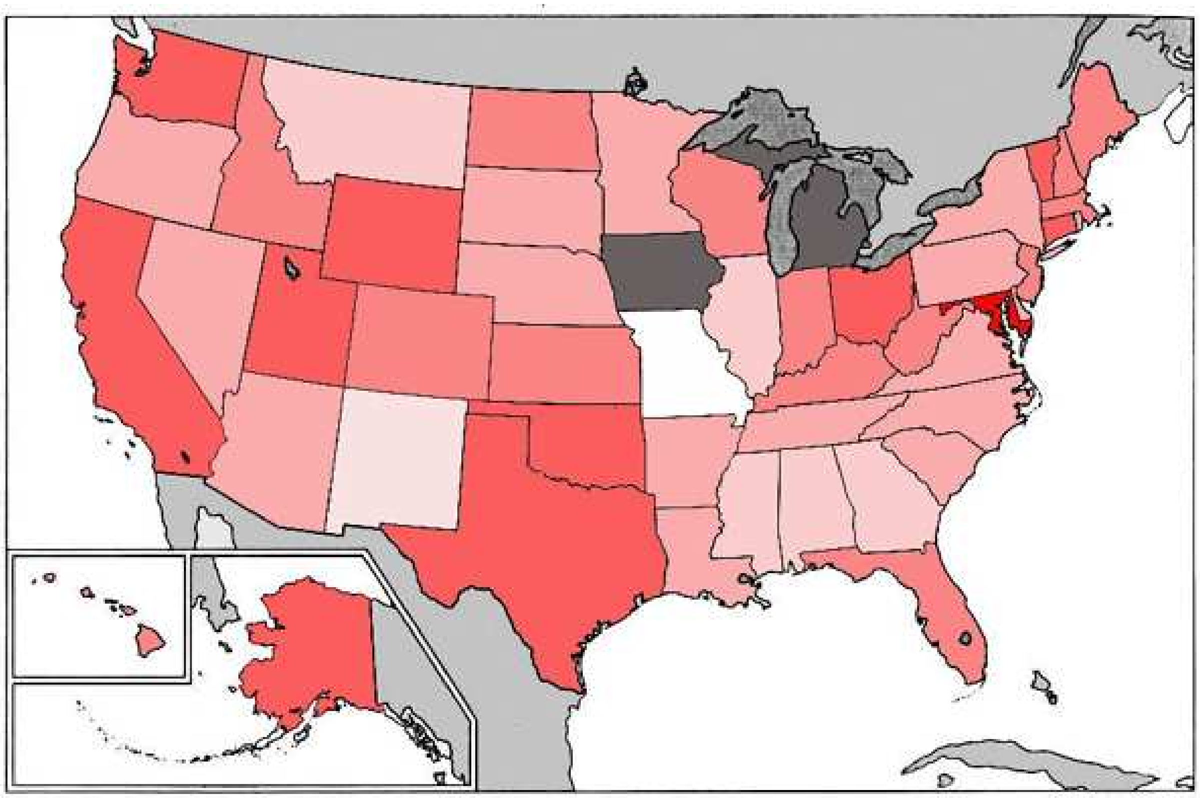

Figure 2. The number of astronomy topics taught in each state. Lighter red means more astronomy, while darker red means less astronomy. This map shows no correlation between political affiliation and amount of astronomy content, or any geographic correlation. Each state seems to go its own way, with no regard for the weather outside.

4. COMPARING THE NRC AND THE STATES' STANDARDS

We compared the states' content standards with the wording of the NRC standards and concluded that 15 of the 45 topics covered in the states were part of the NRC core. This is a bit subjective because the wording varies greatly from state to state. Table 3 summarizes these data. The age at which the topics are taught agrees with the recommendations of the NRC. In addition, most of these 15 topics are among the 15 most commonly taught, suggesting that most states include most of the NRC standards and add to them to build their individualized core standards.

Table 3. The 15 topics that are similar to those in the NRC core. These topics are listed in order of their frequency among states. The average grade in which they are taught compares directly with the NRC suggestion.

Topic	**Number of States**	**Average Grade**	**NRC Suggestion**
Sun properties	48	5	5–8
Moon properties	48	5	K–4, 5–8
Earth’s tilt/seasons	46	6	5–8
Moon phases	46	5	K–4, 5–8
Planets	45	5	5–8
Inner/outer planet characteristics	44	7	5–8
Revolution	38	4	K–4, 5–8
Sun, Moon, stars appear to move east to west	37	3	K–4
Rotation	36	4	K–4, 5–8
Objects in sky	35	2	K–4
Earth’s position in Solar System	33	5	5–8
Gravitational attraction/Newton’s laws	32	7	5–8
Sun "moves" in sky	32	2	K–4
Eclipses	28	6	5–8
Moon/tides	25	7	5–8

Two topics from the NRC core standards are rare in the state standards: the connection between the Moon and tides, and properties of stars. Although gravitational attraction (as the cause for orbital motions) is taught in 32 states, the relationship between the Moon and the tides (gravity as the sole explanation for tides) is taught in only 25 states. A study of the properties of stars (which we consider implicit in the statement that the Sun is an average star) is covered in only half the states, although it could be argued that 32 states cover some kind of stellar astronomy topic (star cycle/properties, H-R diagram, fusion, or spectroscopy).

Curriculum developers are wise in using the NRC standards as a jumping-off point for curriculum development. However, it must be noted that none of the topics is covered in all states, and only seven are covered in more than 80% of states.

Most of these topics, both in the state curricula and the NRC core, are focused on Keplerian astronomy—orbital motions of the Earth and Moon and their consequences. It could be argued that a focus on this phenomenological level detracts from a deeper conceptual understanding for students. One must be careful about drawing too strong a conclusion from this, however, because we have limited this study to the core content standards; we are examining only the "facts." More general goals, such as developing conceptual understanding or critical thinking, may be embedded further down the curriculum chain—at the benchmark level, or at the level of texts or activities.

5. CONTRASTING THE NRC AND THE STATES' STANDARDS

As expected from the pure numbers of topics, the states' standards are more general than the NRC standards and cover a broader range of topics.

None of the NRC standards includes modern astronomical content. The states have attempted to include more recent advances. From stellar astronomy (taught in various incarnations in 32 states) to galaxies (22 states) to the origin of the Solar System (13 states), modern astronomy is making inroads into the K–8 educational system. Only 19 (42%) of the 45 aggregate state standards are Keplerian astronomy. A further 7 (16%) are Solar System topics (which, of course can be quite modern!). This leaves 19 (42%) of the topics to cover the rest of the universe. But the raw numbers do not quite tell us what we want to know. Instead, we consider the weighted percentage, which tells us how commonly a particular field of study is taught. For the Keplerian topics, for example:

W(%) = (sum of all states teaching Keplerian topics)/(sum of all states teaching all topics)
where the sum of all states teaching all topics is 946.

Using this metric, the standards are 52% Keplerian, 23% Solar System, and 25% universe. Without making any judgments about the depth or value of a particular topic, we note that the astronomy learned by students nationwide is heavily weighted toward orbital mechanics of the Earth-Moon-Sun system.

SECTION 6: CONCLUSION

The primary take-away message of this study is that the NRC science standards in astronomy are a great starting place for curriculum developers who wish to address at least some of the topics that are covered in every state. Most teachers, however, are required to teach several topics in addition to, or instead of, these topics. We suspect that these are likely to be the topics with which the teachers themselves struggle most and therefore deserve a focused effort by groups developing curriculum tools for K–8 teachers.

Secondarily, the K–8 curriculum is dominated by Keplerian astronomy. The relative importance of Keplerian versus modern astronomy is a matter for debate among the community at the college introductory level (see a review of the discussion by Jay Pasachoff 2002). Perhaps this debate needs to be extended to the precollege level as well.

Future work involves extending this study to grades 9–12, which is a bit of a challenge. High school courses tend to be topical—students are learning the "big three" of science: biology, chemistry, and physics—and Earth and space sciences are often not part of the statewide curriculum. In addition, the deviation between students becomes much wider at this late period in their schooling; honors or college-bound students study a very different curriculum than other students.

It would be interesting to know what professional astronomers think are the most important topics for K–8 students. Several studies related to Astronomy 101 have been undertaken (Brissenden et al. 1999; Partridge & Greenstein 2002), but the question of what students should know in K–8 has not been explicitly addressed.

Finally, it is unclear how the core curriculum standards translate into the actual learning experience of students in individual classrooms in each state. Having a topic in the core does not mean that it is being taught in the classroom. Assessment of whether the core is being learned most often occurs in the form of standardized tests administered to students at intervals. Particularly in this era of "no child left behind," this type of assessment functions as a stick for teachers: Teach the concepts or else. We would like to know what the carrot looks like; how are teachers being encouraged to include these topics in their classrooms and to seek innovative and interesting ways to teach them?

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APPENDIX

State Core Curriculum Web Pages

Alabama	http://www.alsde.edu/html/sections/documents.asp?section=54&sort=7&footer=sections
Alaska	http://www.eed.state.ak.us/standards/pdf/standards.pdf
Arizona	http://www.ade.state.az.us/standards/science/articulated.asp
Arkansas	http://arkedu.state.ar.us/curriculum/pdf/science_framework_k-8_011006.pdf
California	http://www.cde.ca.gov/be/st/ss/scmain.asp
Colorado	http://www.cde.state.co.us/cdeassess/documents/standards/science.pdf
Connecticut	http://www.state.ct.us/sde/dtl/curriculum/ctframe.pdf
Delaware	http://www.doe.state.de.us/Standards/Science/science_toc.html
Florida	http://www.firn.edu/doe/curric/prek12/index.html
Georgia	http://www.georgiastandards.org/science.aspx
Hawaii	http://standardstoolkit.k12.hi.us/index.html

Idaho	http://www.sde.state.id.us/instruct/standards/documents/subjectpages/Sciencestandardstests.htm
Illinois	http://www.isbe.net/ils/social_science/capd.htm
Indiana	http://www.indianastandardsresources.org/standardSummary.asp?Subject=sci&Grade=
Kansas	http://www.ksde.org/outcomes/sciencestd.html
Kentucky	http://www.education.ky.gov/KDE/Instructional+Resources/Curriculum+Documents+and+Resources/Teaching+Tools/Combined+Curriculum+Documents/default.htm
Louisiana	http://www.doe.state.la.us/lde/uploads/2911.pdf
Maine	http://www.state.me.us/education/lres/review/science_tech_proposed_revised.html
Maryland	http://www.mdk12.org/instruction/curriculum/science/index.html
Massachusetts	http://www.doe.mass.edu/frameworks/scitech/2001/standards/esk_2.html
Minnesota	http://education.state.mn.us/mde/static/000282.pdf
Mississippi	http://www.mde.k12.ms.us/acad/id/curriculum/Science/science_curr.htm
Missouri	http://dese.mo.gov/divimprove/curriculum/webframeworks/05SC.PDF
Montana	http://www.opi.mt.gov/pdf/Standards/ContStds-Science.pdf
Nebraska	http://www.nde.state.ne.us/ndestandards/documents/ScienceStandards.pdf
Nevada	http://www.doe.nv.gov/standards/standscience.html
New Hampshire	http://www.ed.state.nh.us/education/doe/organization/curriculum/Science/ScienceFrameworks.htm#EarthScience
New Jersey	http://www.state.nj.us/njded/frameworks/science/chap8f.pdf
New Mexico	http://nmstandards.org/standards/science/Strand II/SC-CS-03
New York	http://www.emsc.nysed.gov/ciai/mst/pub/mststa4.pdf
North Carolina	http://www.ncpublicschools.org/docs/curriculum/ncecs-science.pdf
North Dakota	http://www.dpi.state.nd.us/standard/content/science/index.shtm
Ohio	http://www.ode.state.oh.us/academic_content_standards/acsscience.asp
Oklahoma	http://www.sde.state.ok.us/acrob/pass/science.pdf
Oregon	http://www.ode.state.or.us/teachlearn/subjects/science/curriculum/gradelevel/
Pennsylvania	http://www.pde.state.pa.us/k12/lib/k12/scitech.pdf
Rhode Island	http://www.ridoe.net/standards/frameworks/science/default.htm
South Carolina	http://ed.sc.gov/agency/offices/cso/standards/science/
South Dakota	http://doe.sd.gov/contentstandards/science/newstandards.asp
Tennessee	http://www.tennessee.gov/education/ci/standards/
Texas	http://www.tea.state.tx.us/rules/tac/chapter112/index.html
Utah	http://www.uen.org/core/science/index.shtml
Vermont	http://www.state.vt.us/educ/new/html/pgm_curriculum/science.html
Virginia	http://www.pen.k12.va.us/VDOE/Instruction/Science/sciCF.html
Washington	http://www.k12.wa.us/CurriculumInstruct/Science/pubdocs/ScienceEALR-GLE.pdf
Washington, DC	http://www.k12.dc.us/dcps/curriculum/curriculum1.html
West Virginia	http://wvde.state.wv.us/policies/p2520.3_ne.pdf

Wisconsin	http://dpi.wi.gov/oea/doc/scifrmwrk.doc
Wyoming	http://www.k12.wy.us/SA/standards/science.pdf