

# Project 2061: Science Content Standards



The Role of Content Standards in U.S.  
Science Education

George E. DeBoer  
Deputy Director, AAAS Project 2061

2009 Shanghai International Forum on  
Science Literacy of Pre-college Students

Shanghai, China  
October 16, 2009

## The themes of today's talk

- History of key developments in the U.S. over the past 25 years
- New initiatives
- Why content standards are important

## I. Background: Science education in the US today

- The US has fifty states and 50 different educational systems.
- Current federal education legislation (No Child Left Behind Act of 2001) requires all states to have content standards in math and reading, to assess students' with respect to those standards each year in grades 3-8 and once in high school, and it requires schools to show improvement in student performance from year to year.
- Each state develops and is responsible for its own content standards and assessments.

## The Place of Science in the No Child Left Behind Act of 2001

- In 2007-08, for the first time, states also had to have content standards in science, and they had to assess students with respect to those standards—once in elementary school, once in middle school, and once in high school.
- However, the test scores in science do not count in determining if a school is considered a successful school, so many schools pay less attention to science than they do to math and reading, especially in elementary school.

## The role of National Standards in Science Education

- Although there is no single set of standards that states must follow, each state has made extensive use of two influential national standards documents when writing and revising their state standards.
- *Benchmarks for Science Literacy*, which was published by AAAS Project 2061 in 1993
- *National Science Education Standards*, which was published by the National Research Council (of the National Academies) in 1996
- These two standards documents have significantly influenced what is now taught in U.S. schools

## Why states are not required to follow a set of national standards

- Under the U.S. constitution, education is not listed as one of the duties of the federal government, so responsibility for education has been retained by the states ever since the federal government was initially formed.
- Most members of the U.S. Congress are reluctant to take the authority for determining the content of the curriculum away from the states.

## Current discussions about common core standards

- Recently, there have been discussions about having all students in the U.S. learn the same common core of knowledge.
- Under proposed plans, this common core would be *optional*. States would be given financial incentives to use the common core and the assessments based on them, but they would not be required to.
- A common core of the most important knowledge and skills is currently being developed in mathematics and English language arts, and a science common core is being discussed.
- The common core would be composed of only the most essential ideas in each content area.
- States would be allowed to make additions to the common core, but they could not leave anything out. If they chose to participate, they would be responsible for teaching and testing the entire core.

## In Summary

- The first formal statements of what students should know and be able to do in science in the U.S. were published in 1993 as *Benchmarks for Science Literacy* and in 1996 as the *National Science Education Standards*.
- During the 1990s, most states used those two documents to guide the writing of their own content standards.
- U.S policy makers are currently engaged in discussions about common core standards that states could voluntarily choose to adopt.

# Project 2061: Science Content Standards



Why are content standards important?

# Project 2061: Science Content Standards



A. They reflect the goals and values of a society

## Examples of educational goals for a society

- To build a society that is science literate—in which citizens understand how the natural and designed world works and appreciate the role of science and technology in society (public understanding of and engagement with science)
- To build a skilled technical workforce
- To create a culture of discovery and innovation
- To enhance the intellectual competence of individuals and provide them with opportunities to pursue their own intellectual interests
- To develop individuals whose contributions to society are most consistent with their own capabilities and interests

Public understanding of science as an educational goal

# Project 2061: Science Content Standards



## Pew-AAAS survey on the public's understanding of science

- A survey of 2001 adults was conducted between April 28 and May 12, 2009 by the Pew Research Center for the People & the Press and AAAS on the current understanding of science by the U.S. public and their attitudes toward science.
- A survey of 2533 members of AAAS (scientists) was conducted from May 1 to June 14, 2009

Which over-the-counter drug do doctors recommend that people take to help prevent heart attacks?

- Antacids
- Cortisone
- Aspirin (91%)

According to most astronomers, which of the following is no longer considered a planet?

- Neptune
- Pluto (60%)
- Saturn
- Mercury

Which of the following may cause a tsunami?

- A very warm ocean current
- A large school of fish
- A melting glacier
- An earthquake under the ocean (77%)

# Project 2061: Science Content Standards



The global positioning system, or GPS, relies on which of these to work?

- Satellites (82%)
- Stars
- Magnets
- Lasers

What gas do most scientists believe causes temperatures in the atmosphere to rise?

- Hydrogen
- Helium
- Carbon dioxide (65%)
- Radon

## How are stem cells different from other cells?

- They can develop into many different types of cells (52%)
- They are found only in bone marrow
- They are found only in plants

## What have scientists recently discovered on Mars?

- Platinum
- Plants
- Mold
- Water (61%)

The continents on which we live have been moving their location for millions of years and will continue to move in the future:

- True (76%)
- False

Lasers work by focusing sound waves:

- True
- False (47%)

Antibiotics will kill viruses as well as bacteria:

- True
- False (54%)

## Electrons are smaller than atoms:

- True (46%)
- False

All radioactivity is man-made:

- True
- False (63%)

# Summary of U.S. Public's Science Knowledge (Adults 18-65+)

# Project 2061: Science Content Standards



<i>Contemporary questions</i>	<i>Percent correct</i>
<i>Aspirin is recommended to prevent heart attacks</i>	91
<i>GPS is reliant on satellites</i>	82
<i>Undersea earthquakes can cause tsunamis</i>	77
<i>Carbon dioxide is gas linked to rising temperatures</i>	65
<i>Water was recently discovered on Mars</i>	61
<i>Pluto is no longer a planet</i>	60
<i>Stem cells can develop into many different types of cells</i>	52

## ***“Textbook” questions***

## ***Percent Correct***

The continents are/have been shifting	76
<i>Not</i> all radioactivity is man-made	63
Antibiotics <i>do not</i> kill viruses as well as bacteria	54
Lasers <i>do not</i> work by focusing sound waves	47
Electrons are <i>smaller</i> than atoms	46

## Differences between scientists and the public on more controversial issues

	Public	Scientists
1. Think that humans and other living things have evolved due to natural processes	32	87
2. Think that the earth is getting warmer because of human activity	49	84
3. Favor the use of animals in scientific research	52	93
4. Favor federal funding for embryonic stem cell research	58	93
5. Favor building more nuclear power plants	51	70
6. Say that all parents should be required to vaccinate their children	69	82

Most of the public thinks that science has had a mostly positive effect on society

	Mostly positive	Mostly Negative
Men	85	5
Women	81	8

## Scientists are viewed favorably in the U.S.

*How much do each contribute to the well-being of society?*

	A lot	Some	Not Much/ Nothing
--	-------	------	----------------------

---

Teachers	77	17	4
Scientists	70	23	5
Medical doctors	69	24	5
Engineers	64	25	6
Journalists	38	41	17
Artists	31	43	22
Lawyers	23	46	27
Business executives	21	43	31

---

## Reasons Why Scientists Chose their Careers

---

	Very Important	Somewhat Important	Not too/Not Important
--	-------------------	-----------------------	--------------------------

---

To solve intellectually

challenging problems

86

13

1

To work for the public good

41

40

19

To make an important discovery

30

44

25

For a financially rewarding career

4

29

66

---

# Project 2061: Science Content Standards



- An informed public is one very important societal goal, and it is reflected in the content of the standards documents in the U.S.
- But there are other goals as well, and these are reflected to a greater or lesser degree in each of the standards documents.

# Project 2061: Science Content Standards



The different emphasis that each standards document takes leads to different strategies for accomplishing those goals

- Benchmarks for Science Literacy
- National Science Education Standards
- Programme for International Student Assessment (PISA)
- Technology and Engineering Standards

Note: “Standards” also include assessment frameworks such as PISA, TIMSS, and NAEP frameworks.

## *Benchmarks for Science Literacy*

- Science, technology, engineering, and mathematics should be learned as a set of richly interconnected ideas, not in isolation from each other.
- Science should be learned by directly observing and interacting with the natural world, and those observations should be linked to broad science principles.
- People should learn to be critical consumers of science. Science ideas should not be accepted without asking questions about their validity.
- In summary: Science education is treated as a broad intellectual activity (in the tradition of a humanistic liberal arts education) (common themes)

## National Science Education Standards

- In addition to many of the ideas found in *Benchmarks*, the *National Science Education Standards* also emphasizes the importance of inquiry as a teaching strategy. For example....
  - Learning science is something students do, not something that is done to them (p. 20).
  - Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers (p. 20).
  - Inquiry into authentic questions generated from student experiences is the central strategy for teaching science (p. 31).
- In summary: Science education is viewed as learning science by doing science.

## OECD Programme for International Student Assessment 2006 Framework (PISA)

- PISA focuses on the everyday application and personal use of science knowledge.
- PISA “measures the capacity of students to identify scientific issues, explain phenomena scientifically and use scientific evidence as they encounter, interpret, solve and make decisions in life situations involving science and technology.”
- “The contexts used for questions were chosen in the light of relevance to students’ interests and lives, representing science-related situations that adults encounter.” These include issues concerning “health, use of resources, environmental quality, hazard mitigation, and advances in science and technology.”
- In summary: Science education is viewed as knowledge and skill that is useful for everyday living.

## Technology and Engineering Standards

- Currently, technology and engineering get very little attention at the K-12 level in the U.S.
- In 2000, the International Technology Education Association, through its Technology for All Americans Project, published *Standards for Technological Literacy*.
- These standards emphasize primarily the social aspects of technology— the importance of citizens' understanding what technology is, how it is created, how it shapes society, and how it is shaped by society.

## The Role of Engineering in K-12 Education

- This year, the National Academy of Engineering and the National Research Council completed a study and a report on *Engineering in K-12 Education*.
- They proposed that much more attention be paid to engineering education in the U.S. to increase the number of students preparing for technical careers, and to increase the technological literacy of all students.
- They recommended exploring the feasibility of using engineering design as a unifying principle in science-technology-engineering-mathematics (STEM) education.

## In summary

- *Benchmarks*: A broad intellectual activity (conceptual understanding and critical thinking)
- *National Science Education Standards*: Practice doing science (science as inquiry; hands-on activity as the most effective way to understand the nature of science)
- *PISA*: Useful knowledge and skill (everyday applications of science for personal use)
- *Engineering/Technology Standards*: Preparation for technical careers; public understanding of engineering and technology.

# Project 2061: Science Content Standards



## A. Content standards reflect the values of a society

### B. Content standards can impact practice

- Each of these standards documents has had its particular influence on educational systems both in the U.S. and around the world and continues to do so.
- Countries, states, and local school districts use content standards to guide the direction of science education, and they pay attention to how well students perform on tests aligned to those standards.
- For example, countries pay attention to the results of tests like PISA, and the European Union strongly supports an IBSE (inquiry-based science education) approach to science teaching.

## C. Standards provide coherence to the educational system

- Not only do standards reflect the values of a society and influence the broad direction of science education policy, regardless of its emphasis—on inquiry, conceptual understanding, critical reasoning, engineering design, or practical problem solving—a well thought out standards document can help make education more effective and efficient.

## Standards can be used to harmonize the educational system

- They guide the selection of content for instruction, the curriculum, and assessment.
- They have the potential to integrate instruction, curriculum, and assessment so that they work in harmony to improve student learning.

## 1. Achieving coherence

- In the U.S., educational researchers are beginning to describe sets of interconnected ideas that help students develop coherent mental models of various aspects of the natural world that can become more sophisticated over time.
- They are creating both horizontal integration (connections between related ideas at the same grade level) and vertical integration (connections between ideas from one grade level to the next).
- These then become the target for instruction and assessment.
- The *Atlas of Science Literacy* as an example

## *Atlas of Science Literacy (2001, 2007)*

- *The Atlas of Science Literacy* is a collection of nearly 100 conceptual strand maps that show the connectedness of science ideas.
- The maps help educators make vertical and horizontal links among specific science ideas, and connections across topics.

## Making Connections Between Science Ideas



Strand maps show the horizontal and vertical connections among science ideas.

Articulation from K-12

THE PHYSICAL SETTING  
WEATHER AND CLIMATE (4B)

The earth has a variety of climatic patterns, which consist of different conditions of temperature, precipitation, humidity, wind, air pressure, and other atmospheric phenomena. These result from a variety of factors. Climate and changes in climate have influenced in the past and will continue to influence what kinds of life forms are able to exist. Understanding the basic principles that contribute to maintaining and causing changes in weather and climate increases our ability to forecast and moderate the effects of weather and to make informed decisions about human activities that may contribute to climate change.

The map is organized around four strands—*temperature and winds, water cycle, atmosphere, and climate change*. The progression of understanding begins in the elementary grades with observations about heat transfer, changes in water from one state to another, and changes in weather over the course of a day and over the course of seasons. By middle school, the focus is on the water cycle, patterns of change in temperature, and the notion of climate change. In high school, seasons and winds and the water cycle are related to gravity and the earth's rotation, and climate change is related to natural causes and human activities.

Benchmarks in this map about temperature and winds draw on ideas about heat transfer and transformation in the **ENERGY TRANSFORMATIONS** map. Benchmarks in the *climate change* strand are also related to the **SCIENCE AND SOCIETY** map. The widespread use of climate models to improve our understanding of the earth's climate system and climate change suggests a connection to benchmarks in the **MODELS** map as well.

NOTES

The left-hand side of the *temperature and winds* strand presents a progression of understanding of seasons. The explanation of the seasons in terms of the tilt of the earth requires students to engage in fairly complex spatial reasoning. For this reason, although the idea is introduced at the 6-8 grade level in *Benchmarks*, the map places it (4B/H3) at the 9-12 level.

Benchmarks related to the heating of materials and the transfer of thermal energy lay the conceptual groundwork for understanding solar heating, global circulation, seasonal weather patterns and climate, and the effect of greenhouse gases. To understand how thermal energy moves in both oceanic and atmospheric systems, students need to know that convective currents are an essential mechanism that aids in that movement. In middle school, understanding of convection currents is linked to experiences with relevant phenomena. Understanding convection in terms of gravity, buoyant forces, and pressure is not expected until high school. It is not necessary for students to have a molecular comprehension of thermal energy to be able to understand atmospheric and oceanic circulation patterns and their role in climate.

Several lines of conceptual development converge in the new 9-12 benchmark that begins "Climatic conditions result from..." These include an understanding of temperature patterns over the earth, atmospheric and oceanic circulation patterns, and the water cycle. A double-headed arrow between this benchmark and another new benchmark (4B/H6) on climate change indicates that they are closely related but that neither is conceptually dependent on the other.

Before students understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990; Krikel, Watson, & Glazier, 1998). With special instruction, some students in 5<sup>th</sup> grade may be able to identify the air as the final location of evaporating water (Russell & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). For many students, difficulty understanding the existence of water vapor in the atmosphere persists in middle school years (Lee et al., 1993; Johnson, 1998). Students can understand rainfall in terms of gravity once they attribute weight to little drops of water (typically in upper elementary grades), but the mechanism through which condensation occurs may not be understood until high school (Bar, 1989).

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andesson & Wallin, 2000; Koulaidis & Christidou, 1998; Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andesson & Wallin, 2000).

See **ENERGY RESOURCES** and **ENERGY TRANSFORMATIONS** for additional research.

© 2007 AAAS Project 2061



RESEARCH IN BENCHMARKS

Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vossliado, 1991). Many students before and after instruction in earth science think that winter is colder than summer because the earth is farther from the sun in winter (Atwood & Atwood, 1996; Dove, 1998; Phillips, 1991; Sadler, 1998). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galli & Lavrik, 1998; Sadler, 1998). Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter (Galli & Lavrik, 1998; Sadler, 1998). Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons (Galli & Lavrik, 1998; Salermo, Edelson, & Sherin, 2005). For example, some students believe that the side of the sun not facing the earth experiences winter, indicating a confusion between the daily rotation of the earth and its yearly revolution around the sun (Salermo, Edelson, & Sherin, 2005).

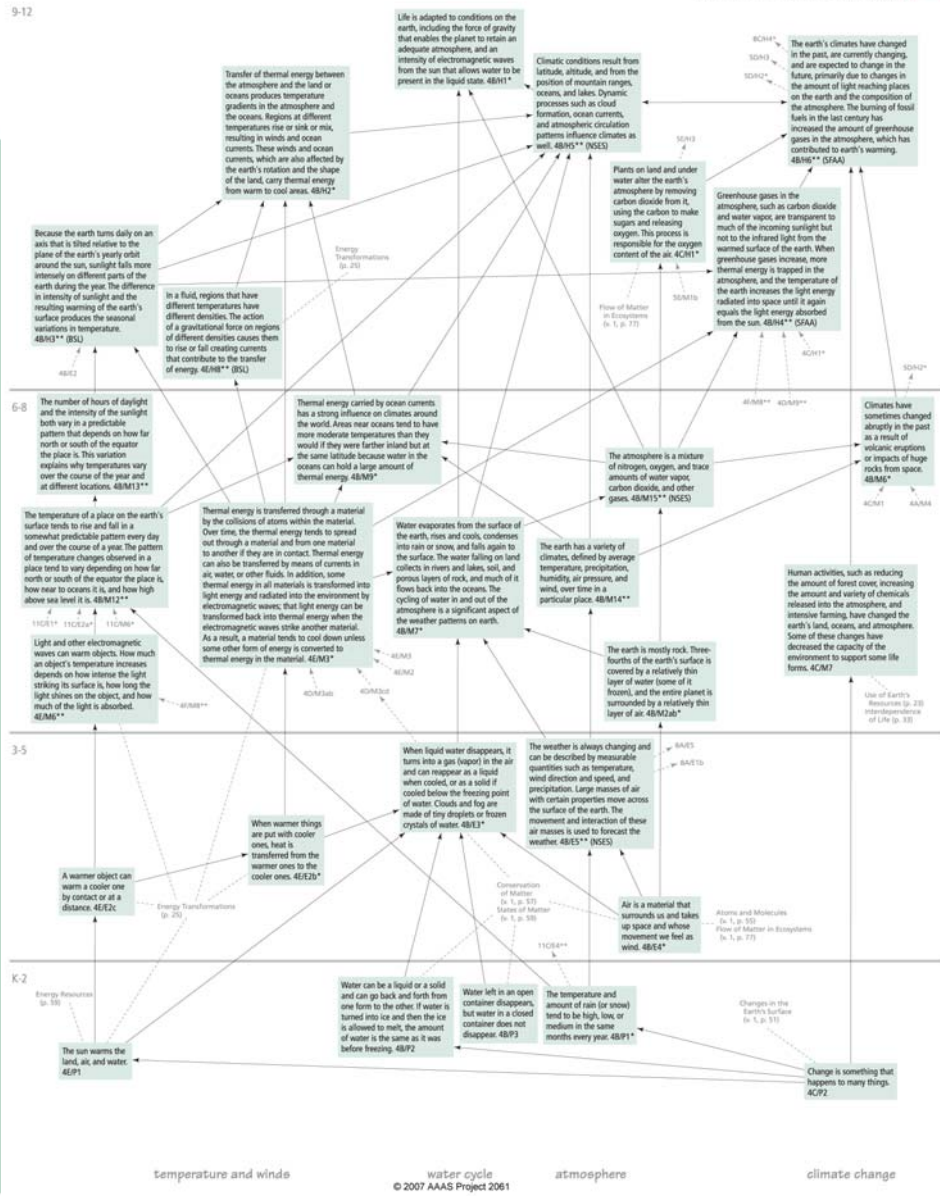
Although upper elementary students may identify air as existing even in static situations and recognize that it takes space, recognizing that air has weight may be challenging even for high-school students (Sere, 1985; Driver et al., 1994a; Krikel, Watson, & Glazier, 1998). Students of all ages (including college students) may believe that air exerts force or pressure only when it is moving and only downwards (Driver et al., 1994a; Sere, 1985; Henriques, 2002; Nelson, Aron, & Franck, 1992). Only a few middle-school students use the idea of pressure differences between regions of the atmosphere to account for wind; instead, they may account for winds in terms of visible moving objects or the movement of the earth (Driver et al., 1994a).

Before students understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990; Krikel, Watson, & Glazier, 1998). With special instruction, some students in 5<sup>th</sup> grade may be able to identify the air as the final location of evaporating water (Russell & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). For many students, difficulty understanding the existence of water vapor in the atmosphere persists in middle school years (Lee et al., 1993; Johnson, 1998). Students can understand rainfall in terms of gravity once they attribute weight to little drops of water (typically in upper elementary grades), but the mechanism through which condensation occurs may not be understood until high school (Bar, 1989).

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andesson & Wallin, 2000; Koulaidis & Christidou, 1998; Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andesson & Wallin, 2000).

See **ENERGY RESOURCES** and **ENERGY TRANSFORMATIONS** for additional research.

© 2007 AAAS Project 2061





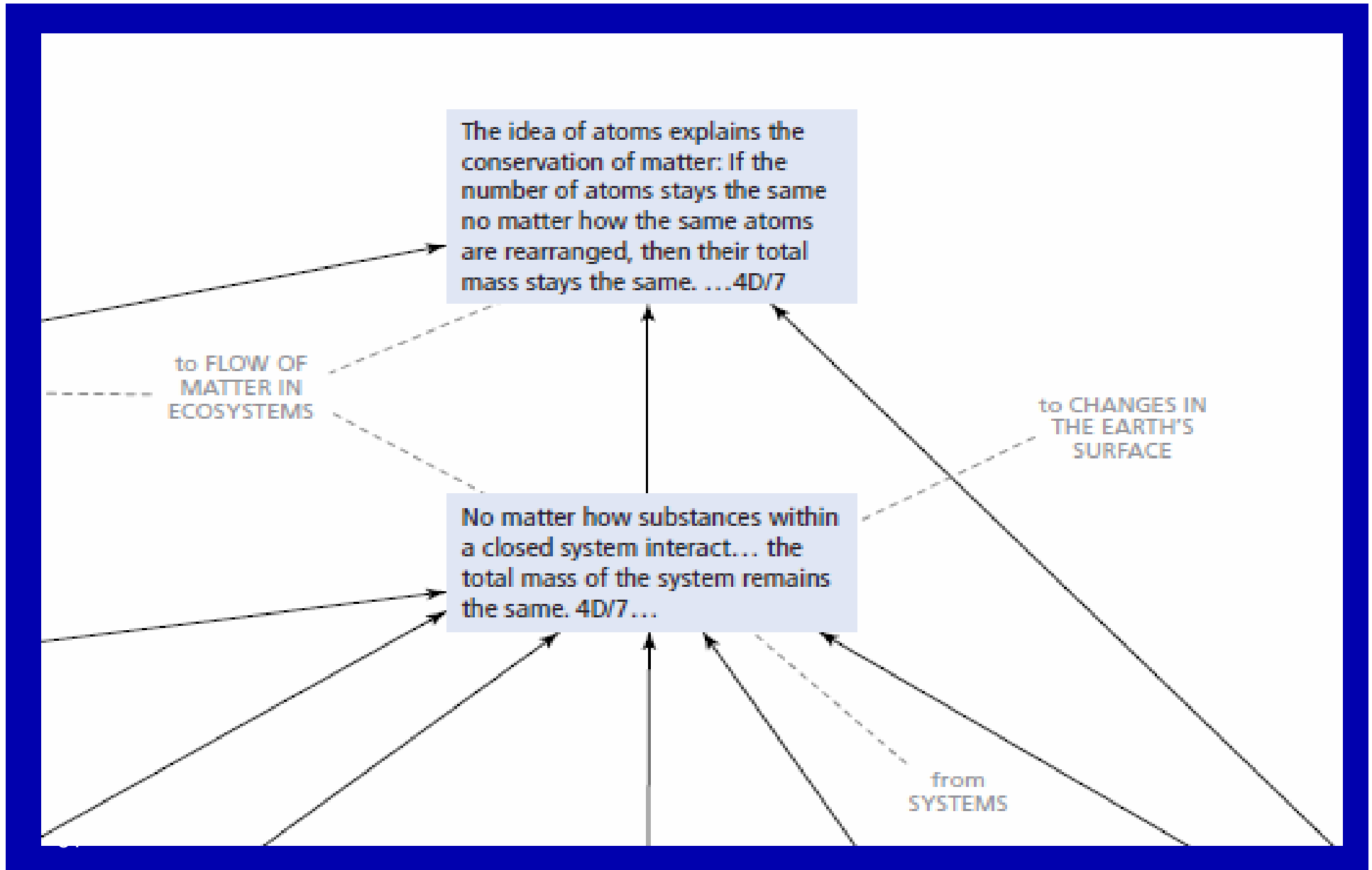
# Project 2061: Science Content Standards



- Examples of specific connections



# Project 2061: Science Content Standards



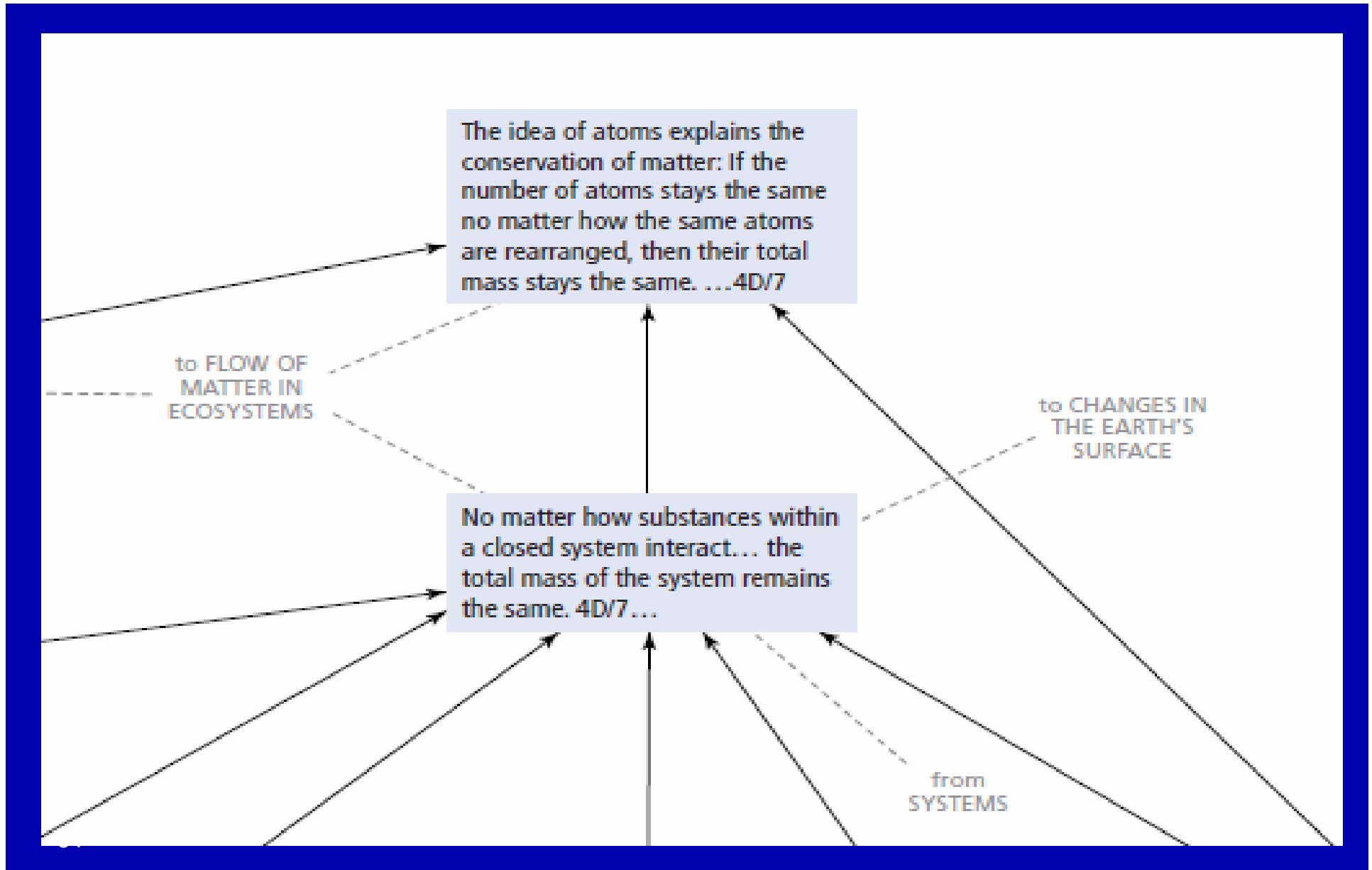
## Connecting the substance level and atomic level ideas about conservation of matter

- The substance-level statement provides a rule to be applied to observations, but the atomic-level statement provides a mental model of atoms as objects whose mass cannot change.
- This model of atoms can then be used to explain the real-world observations having to do with conservation of matter.

## Other connections

- Notice that the map also connects ideas of conservation to the flow of matter and energy in ecosystems and to changes in the earth's surface. Both of those systems involve the cycling of matter in which matter is conserved.
- Student ideas about growth, decay, erosion, mountain building, etc. often show that they do not appreciate that matter is conserved. (Growth just happens.)

# Project 2061: Science Content Standards



## 2. The role of content standards in assessment

- Content standards also provide a basis for holding students, teachers, and school systems accountable for the science ideas specified in the content standards.
- And content standards provide a basis for analyzing and diagnosing what students know about the ideas specified in the content standards so that instruction can be adjusted to improve student understanding of those ideas.
- To do this effectively, assessments must be carefully aligned to the content standards.

## Project 2061: Science Content Standards



A student placed a solid substance and a liquid substance in a jar and sealed it. After a few minutes, she noticed that gas bubbles had formed and the solid substance had disappeared. What happened to the mass of the jar and everything in it after the reaction occurred and why?

- A. The mass decreased because some atoms were destroyed when the solid disappeared. (26%)
- B. The mass increased because new atoms were created when the gas bubbles formed. (25%)
- C. The mass stayed the same because no atoms were destroyed or created. (29%)
- D. The mass stayed the same because some atoms were destroyed, but an equal number of atoms were created. (20%)

(71% think that atoms can be created or destroyed.)

## Project 2061: Science Content Standards



A student has two different liquids in open jars. She pours the liquid from one jar into the other jar, and she observes bubbles. After the bubbling stops, she finds that the total weight of the liquids is now less than the total weight of the liquids before they were mixed together. [With diagram]

How can her observation be explained?

- A. Some atoms went into the air. (14%)
- B. Some atoms were destroyed. (21%)
- C. Some atoms became heavier. (15%)
- D. Some atoms became lighter. (50%)

(65% think that the mass of atoms can change, and 21% think they can be destroyed.)

## Project 2061: Science Content Standards



Two liquids and one gas react chemically with one another in a sealed jar. Which of the following explains why the total mass of everything in the jar is the same before and after the reaction?

- A. The number of molecules stays the same. (35%)
- B. The number of substances stays the same. (20%)
- C. The number of liquids and gases stays the same. (19%)
- D. The number of each kind of atom stays the same. (26%)**

(More students think that molecules rather than atoms are conserved. Students may be confusing atoms and molecules.)

## Summary

- Content standards should reflect the goals and values of a society and should be used to guide the educational system toward meeting those goals and values.
- Content standards can help to create an educational system in which all aspects of the system are in harmony, with curriculum materials, instruction, and assessment all focused on the same learning goals.
- Content standards can be linked together both horizontally and vertically to support students in developing coherent mental models that can be used to explain natural phenomena.
- But to accomplish these outcomes, content standards must be clearly stated, and instruction, curriculum, and assessment must be carefully aligned to those content standards. This takes hard work!

# Project 2061: Science Content Standards



Thank You!

## Examples of diagnostic assessment items

## Project 2061's Agenda for Future Work

- Continue to support the development and revision of science content standards to promote a coherent and integrated approach to science learning.
- Continue to develop models of assessment that test for conceptual understanding.
- Continue to develop workshops to help teachers and other educators align instruction to clearly stated learning goals and to teach and test for conceptual understanding.
- Develop tools and resources to influence the preparation of new science teachers.
- Develop curriculum materials aligned to the ideas in *Benchmarks* and the *National Science Education Standards*.

## A coherent approach to science content

- At Project 2061, we are working on developing sets of interconnected ideas of such things as how the nature and behavior of atoms and molecules explain natural phenomena; or the nature of the interactions between organisms in ecosystems and how matter flows through an ecosystem; or a model of the energy that is transferred between the sun, land, oceans, and the atmosphere, and how that transfer of energy drives weather and climate.

## Atoms, Molecules, and States of Matter

- All matter is made up of atoms.
- All atoms are extremely small.
- All atoms and molecules are in constant motion.
- There are differences in the spacing, motion, and interaction of atoms and molecules that make up solids, liquids, and gases.
- For any single state of matter, increasing the temperature typically increases the distance between atoms or molecules. Therefore, most substances expand when heated.
- When heated, solids can change into liquids and liquids can change into gases. When cooled, gases can change into liquids and liquids can change into solids. These changes of state can be explained in terms of changes in the proximity, motion, and interaction of atoms and molecules.
- For any single state of matter, the average speed of the atoms or molecules increases as the temperature of a substance increases and decreases as the temperature of a substance decreases.

## Substances, Chemical Reactions, and Conservation

- A pure substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the substance and can be used to identify it.
- Many substances react chemically in predictable ways with other substances to form new substances with different characteristic properties.
- When substances interact to form new substances, the atoms that make up the molecules of the original substances rearrange into new molecules.
- No matter how substances within a closed system interact with one another, the total mass of the system remains the same.
- Whenever atoms interact with each other, regardless of how they are arranged or rearranged, the total mass stays the same.

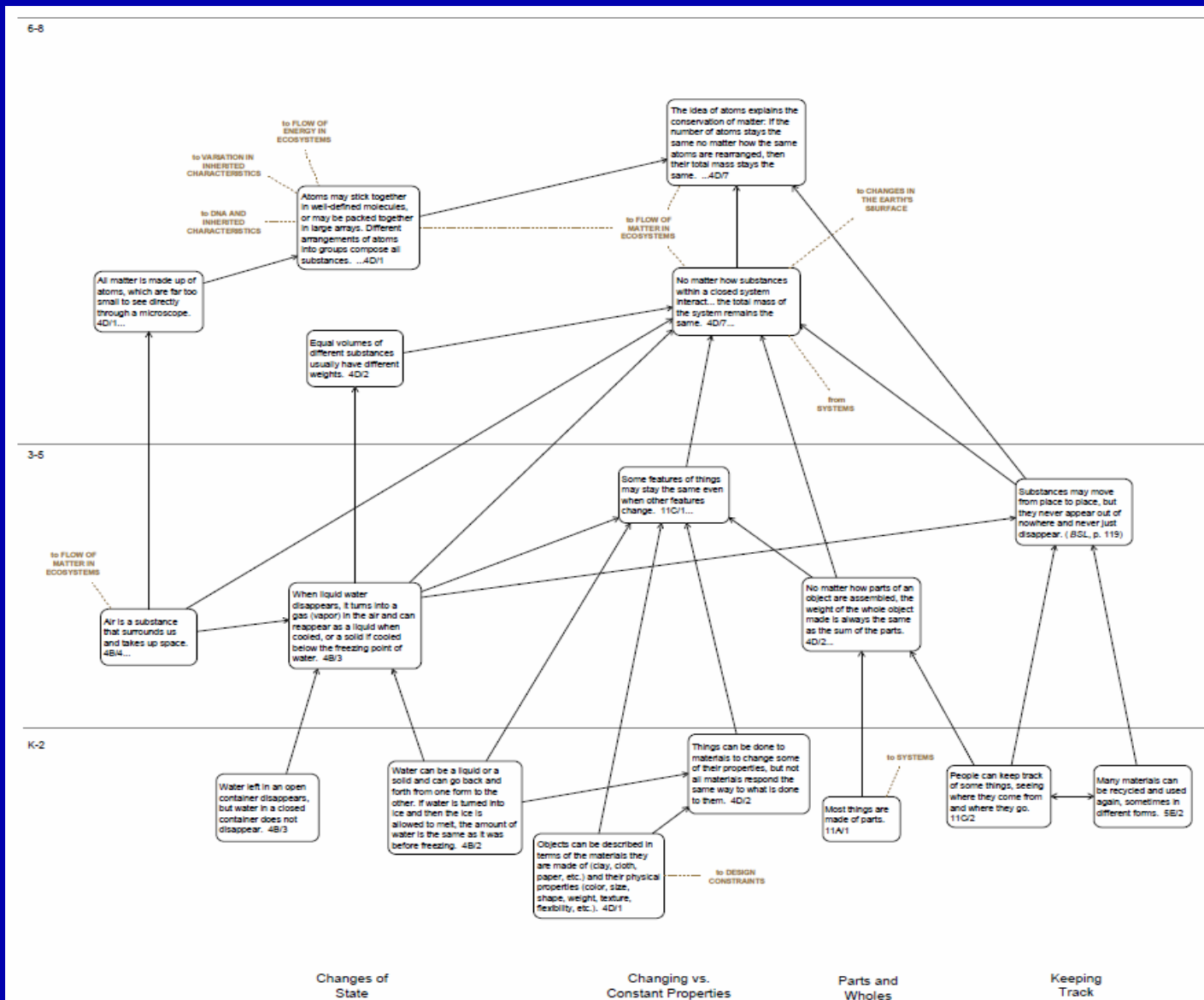
## Atoms and Molecules

- All matter is made up of atoms.
- All atoms and molecules are in constant motion.
- There are differences in the spacing, motion, and interaction of atoms and molecules that make up solids, liquids, and gases.
- For any single state of matter, increasing the temperature typically increases the distance between atoms or molecules. Therefore, most substances expand when heated.
- When substances interact to form new substances, the atoms that make up the molecules of the original substances rearrange into new molecules.
- No matter how substances within a closed system interact with one another, the total mass of the system remains the same.
- Whenever atoms interact with each other, regardless of how they are arranged or rearranged, the total mass stays the same.

## Using *Atlas* maps

- To help us think about the interconnections among ideas, both from grade band to grade band and across different concepts, we make use of the maps that we developed for the *Atlas of Science Literacy*.

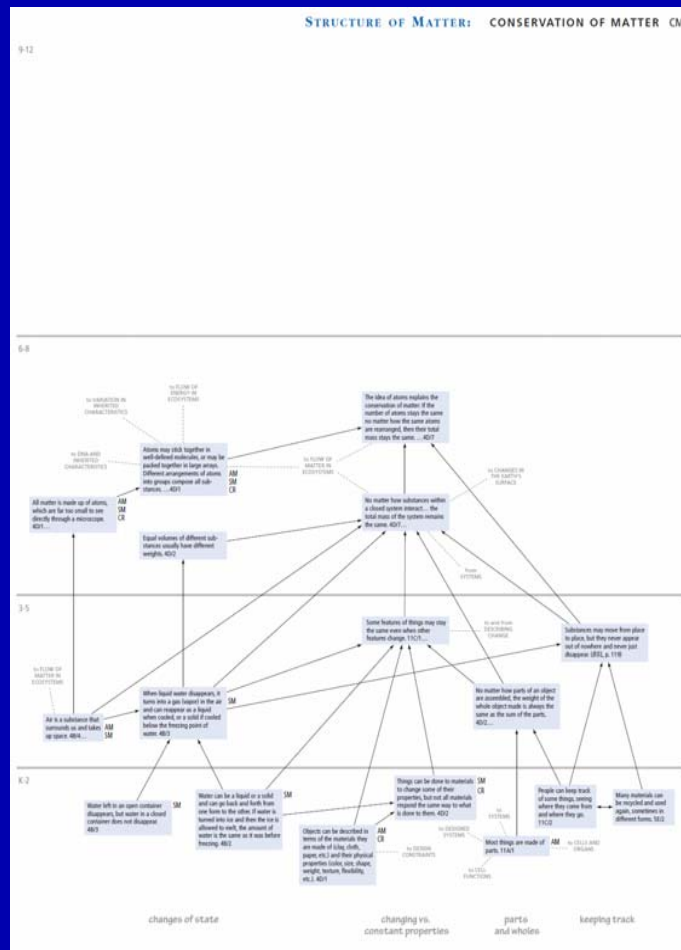
# Project 2061: Science Content Standards







# Project 2061: Science Content Standards



When describing mental models, we describe both the connections between ideas and the boundaries of the model

- Connections : Which ideas can be linked together?
- Clarification of boundaries: Which ideas are both relevant to the mental model and within the ability level of the students to comprehend, and which ideas go beyond what they are likely to comprehend?

## Project 2061: Science Content Standards



Conservation of matter can be described at either the substance level, the atomic level, or both.

No matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same. (*Benchmarks for Science Literacy*, 4D/M7a)

The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how the same atoms are rearranged, then their total mass stays the same. (*Benchmarks for Science Literacy*, 4D/M7b)

## Substance-level boundary clarification

- Students should know that when substances mix, undergo chemical reactions, change state, or dissolve, or when objects are cut or broken into smaller pieces, the total mass of all the matter will always remain the same. They should know that regardless of the form that the products of these processes may take (for example, when a sugar cube dissolves in water or a chemical reaction produces a gas), the mass will always stay the same. Students should know that if it appears that the mass has changed, it is because some material has not been accounted for. Students should know that since light is not matter, its presence or absence does not affect the mass of the matter.

## Atomic-level boundary clarification

- Students should know that atoms are not created or destroyed when substances mix, undergo chemical reactions, change state, or dissolve, or when objects are cut or broken into smaller pieces. They should know that the total number of each kind of atom always remains the same regardless of what happens to the matter (mixing, chemical reactions, changes of state, dissolving, or objects being cut or broken into smaller pieces). Students are expected to know that the mass of an atom does not change. They are expected to know that if the measured mass has changed, it is because some atoms have not been accounted for. Students are not expected to know that mass is not conserved in energy-mass conversions such as nuclear reactions or other subatomic interactions.

## AAAS supports a common core in science

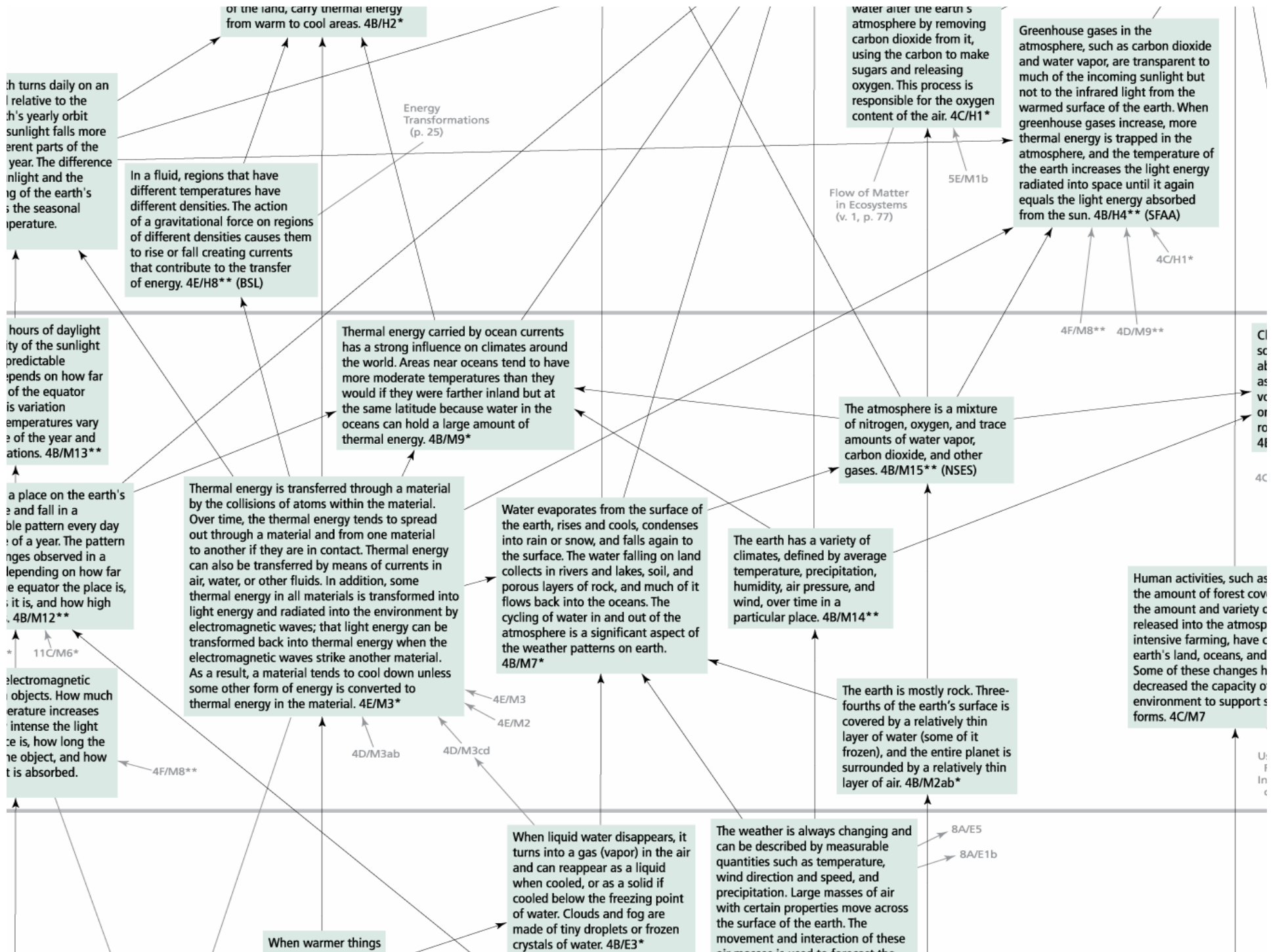
- "Voluntary, nationwide education standards in science, along with reading and math, are the next logical step" toward improving K-12 education in America, according to commentary published 10 June 2009 in the *Houston Chronicle*. (Leshner and Roseman article)

## Project 2061: Science Content Standards



But AAAS is also encouraging policy makers to make use of content standards that were previously written

- National science education standards don't need to be created "from scratch." National standards for science learning could be based on well-tested, widely accepted guidelines set forth by Project 2061, the National Research Council, the National Council of Teachers of Mathematics, and the National Assessment of Educational Progress, Leshner wrote 15 August 2007 in the *Washington Times*.



# Project 2061: Science Content Standards



Example: Conservation of Matter