Tools for Climate Literacy Educators
Project 2061's Design Tools

February 18, 2010

San Diego, CA

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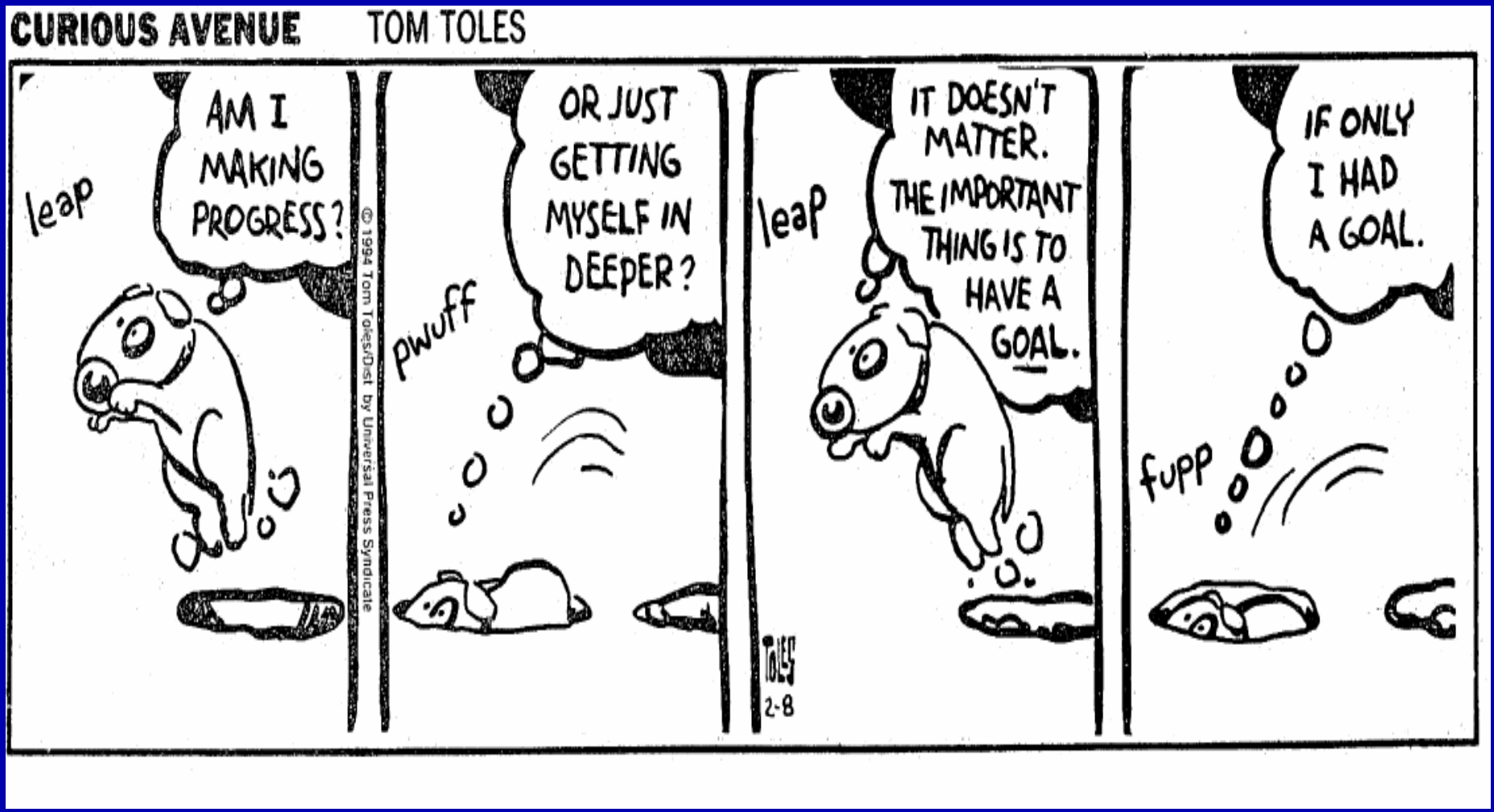
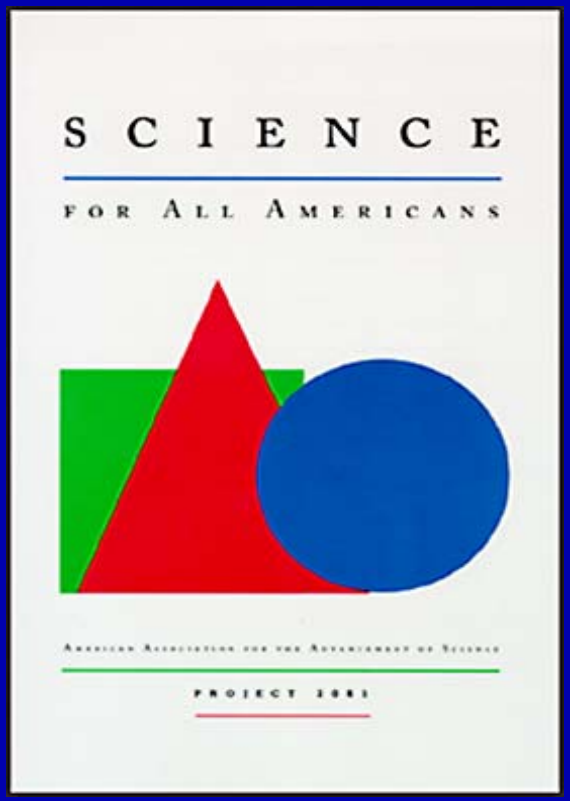
AAAS Project 2061

Learning Goals are an Essential First Step

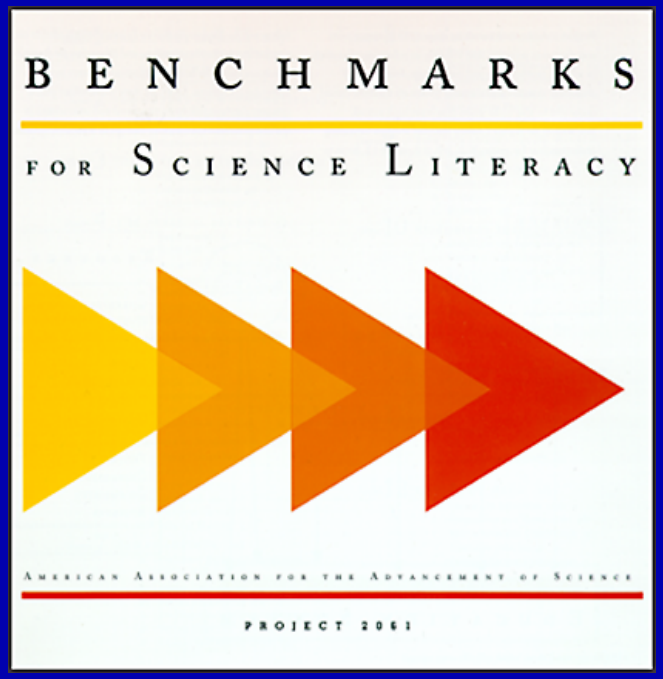


Characterizing Adult Literacy in Science Mathematics, and Technology



THE NATURE OF SCIENCE
THE NATURE OF MATHEMATICS
THE NATURE OF TECHNOLOGY
THE PHYSICAL SETTING
THE LIVING ENVIRONMENT
THE HUMAN ORGANISM
HUMAN SOCIETY
THE DESIGNED WORLD
THE MATHEMATICAL WORLD
HISTORICAL PERSPECTIVES
COMMON THEMES
HABITS OF MIND

K-12 steps toward science literacy



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K-12 Connections among steps

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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.

RESEARCH IN *BENCHMARKS*

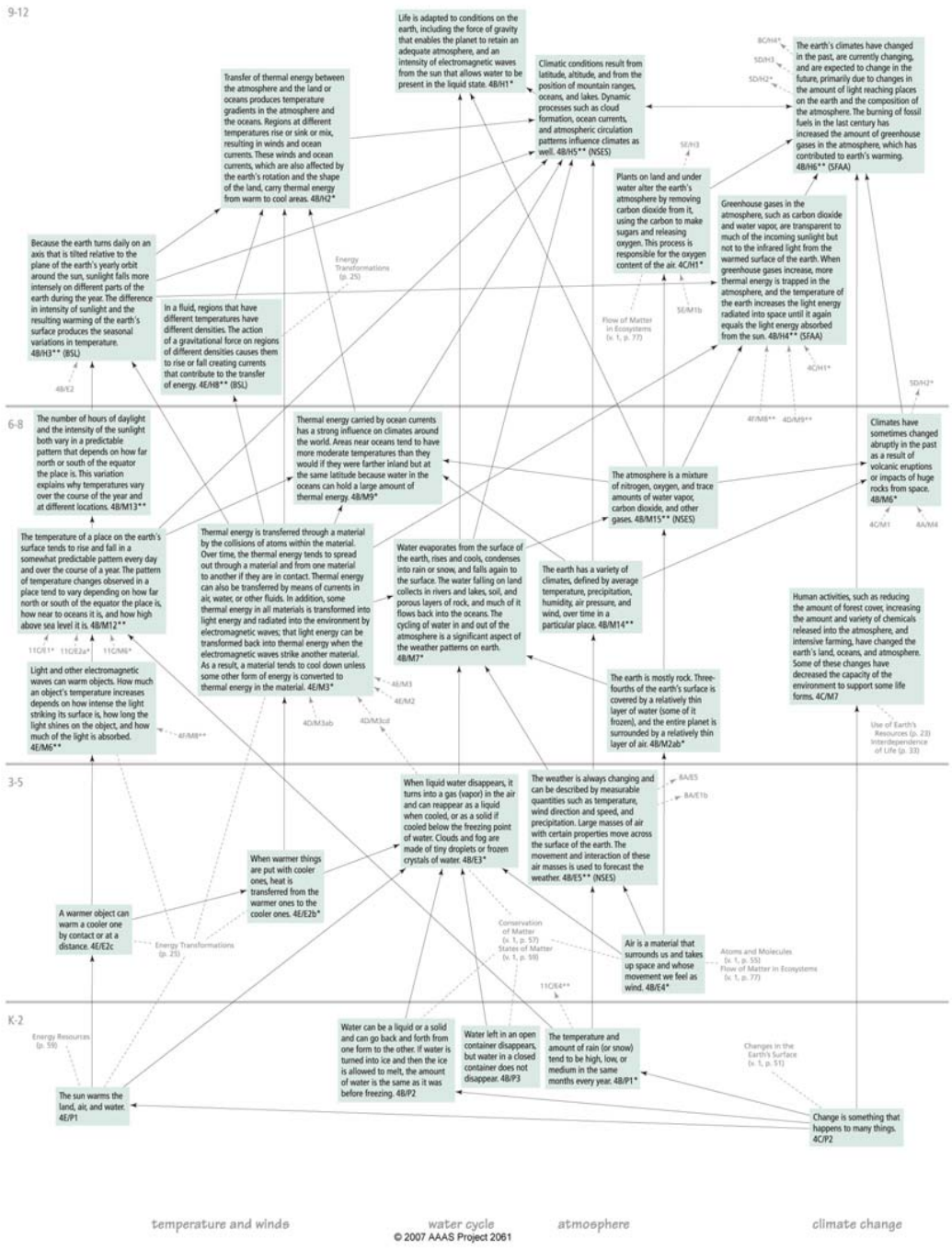
Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vosniadou, 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; Philips, 1991; Sadler, 1998). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galili & 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 (Galili & 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 (Galili & Lavrik, 1998; Salierno, 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 (Salierno, 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; Krnel, Watson, & Glazar, 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, & Francek, 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; Krnel, Watson, & Glazar, 1998). With special instruction, some students in 5th 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) (Andersson & 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 (Andersson & Wallin, 2000).

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



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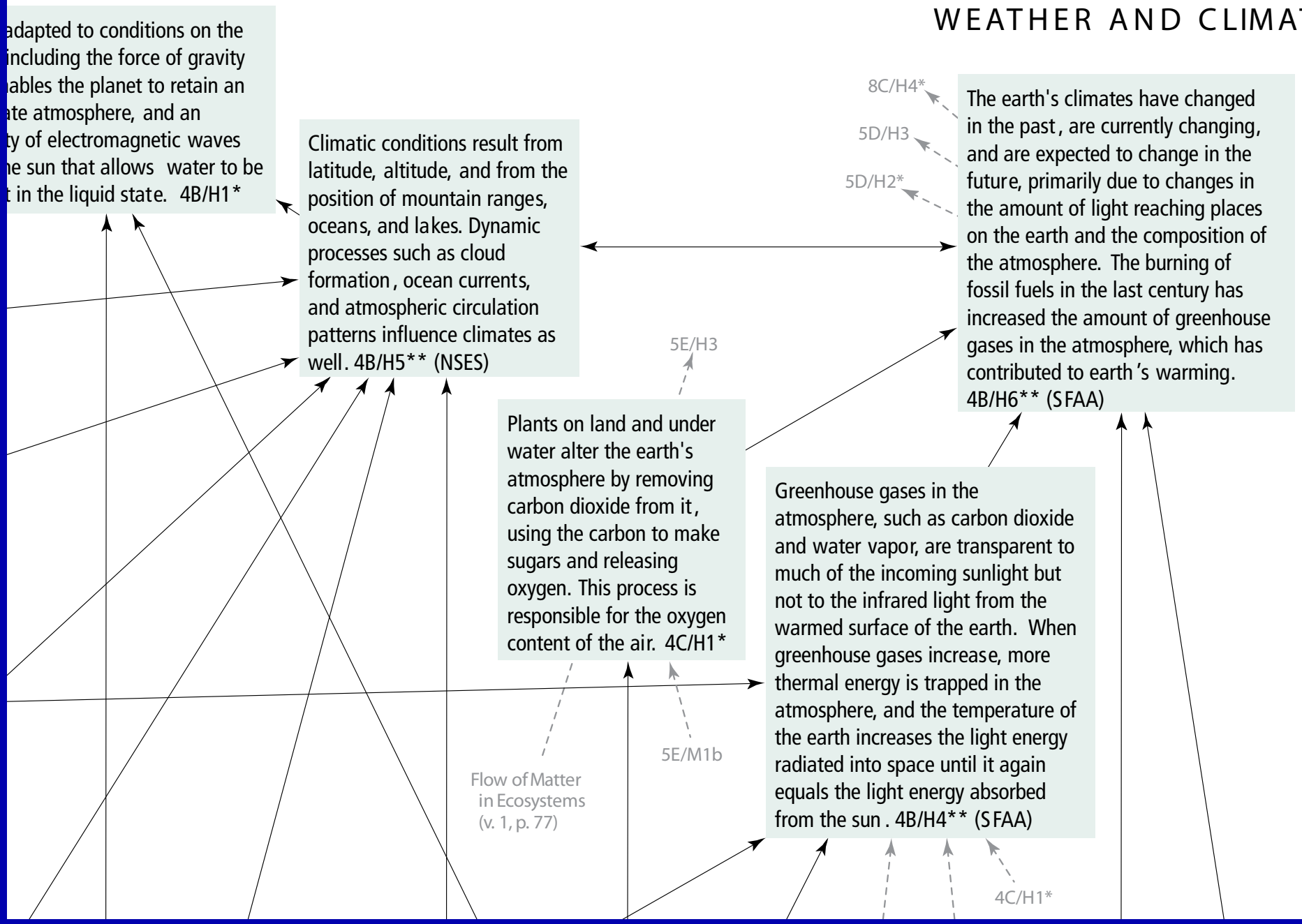
WEATHER AND CLIMATE



The number of hours of daylight and the intensity of the sunlight both vary in a predictable pattern that depends on how far north or south of the equator the place is. This variation explains why temperatures vary over the course of the year and at different locations. 4B/M13**

Thermal energy carried by ocean cur has a strong influence on climates a the world. Areas near oceans tend t more moderate temperatures than t would if they were farther inland bu the same latitude because water in oceans can hold a large amount of thermal energ y. 4B/M9*

The temperature of a place on the earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. The pattern of temperature changes observed in a place tend to vary depending on how far north or south of the equator the place is, how near to oceans it is, and how high above sea level it is. 4B/M12**

Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. Thermal energy can also be transferred by means of currents in air, water, or other fluids. In addition, some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material. As a result, a material tends to cool down unless some other form of energy is converted to thermal energy in the material . 4E/M3*

Wate the e into r the su colle porou flows cyclin atmo the w 4B/M

11C/E1* 11C/E2a* 11C/M6*

Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed. 4E/M6**

4E/M3

4E/M2

4D/M3ab

4D/M3cd

4F/M8**

Taking Learning Goals Seriously

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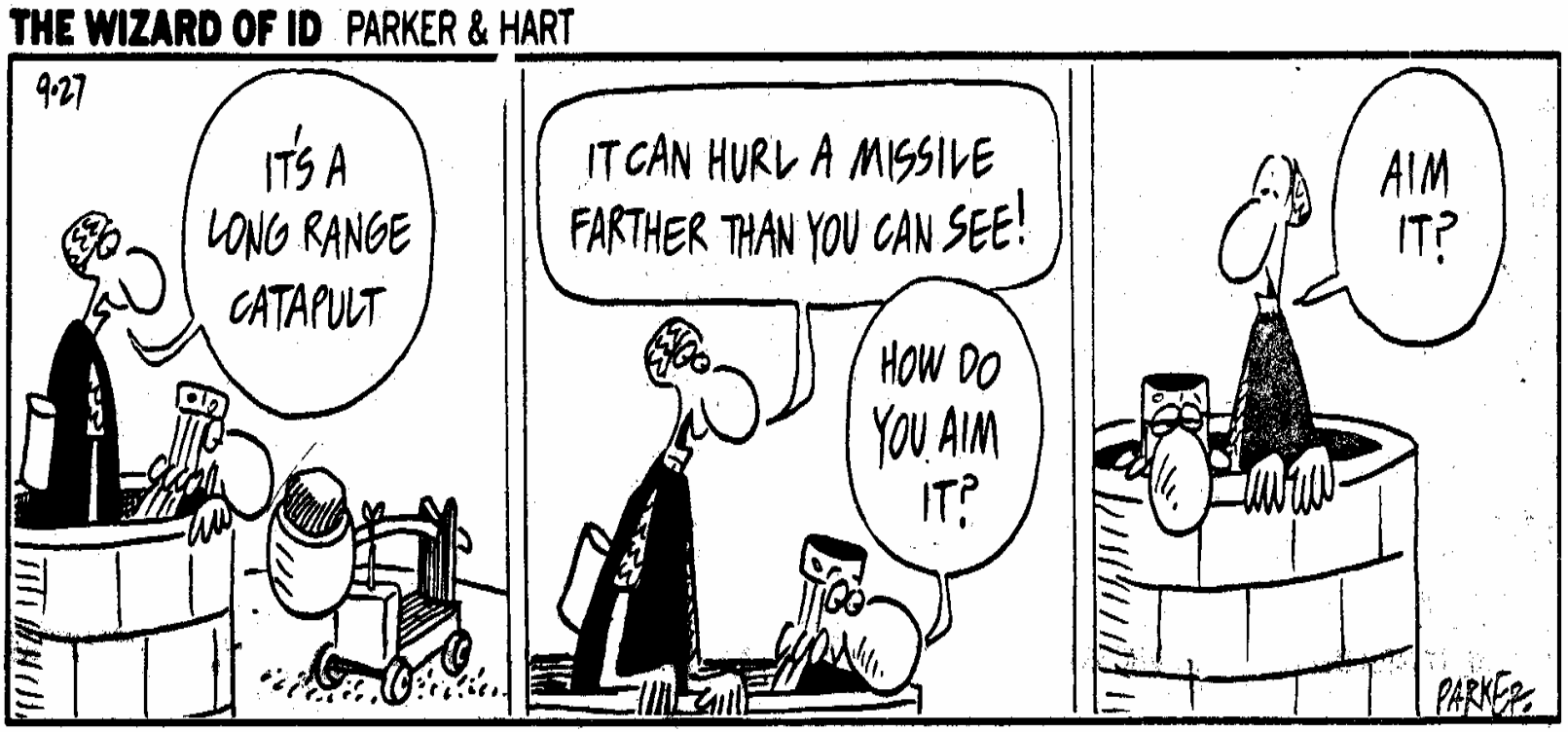
Aligning Curriculum, Instruction, and Assessment with Learning Goals



Resources Project 2061 is Developing

- Clarifications of benchmark ideas
- Descriptions of common student misconceptions
- Assessment items
- Descriptions of phenomena and representations
- Assessment items
- Web-based interfaces

We wish to thank NSF, NOAA, and NASA for funding this important work.

Selected Key Ideas for Middle School

Idea A. Air has measurable properties such as temperature, humidity, speed, and direction, and those properties can change.

Idea B. The pattern of the rise and fall of temperatures over a day and over a year is due to changes in the angle that sunlight hits any place on the surface of the earth.

Idea C. Wind results primarily from differences in heating between the equator and the poles and the earth's rotation.

Idea D. The amount of water vapor in the air depends on the amount of liquid water available, the temperature of the air, and where the air is coming from.

Idea E. Clouds and rain form as air cools and water vapor in the air condenses into water droplets.

Excerpt from Clarification of Idea B

Students are expected to know that:

- Energy from the sun (sunlight) warms the earth's surface and the air; but the air is warmed mostly by energy absorbed by the oceans and land and transferred to the air. The more energy that is transferred to the surface of the earth, the more the surface of the earth and the air above it are warmed. The less energy that is transferred to the surface of the earth, the less the surface of the earth and the air above it are warmed.
- As the sun's position in the sky changes, the angle at which sunlight strikes any place on the surface of the earth changes. The higher the sun appears above the horizon, the larger the angle at which the sunlight hits the surface of the earth. The closer the sun appears to the horizon, the smaller the angle at which the sunlight hits the surface of the earth. These differences in angle result in differences in the sun's energy reaching the earth's surface and, hence, in the amount of energy transferred to the air.

Limitations of Available Learning Research

- Few ideas about Climate Literacy have been investigated; most studies have focused on why there are seasons.
- The few studies relevant to Climate Literacy Learning Goals rely on a small number of questions and involve small numbers of students.
- Project 2061's pilot testing has failed to confirm most of the reported misconceptions.

Sample Assessment Item
Used in Pilot Test

Does sunlight warm the air around the earth directly, or does sunlight first warm the land, which then warms the air?

A. Sunlight warms the air directly, but sunlight does not warm the land and the land does not warm the air.

B. Sunlight warms both the air and the land directly, but the land does not warm the air. (19%)

C. Sunlight warms both the air and the land directly, and the land warms the air. (36%)

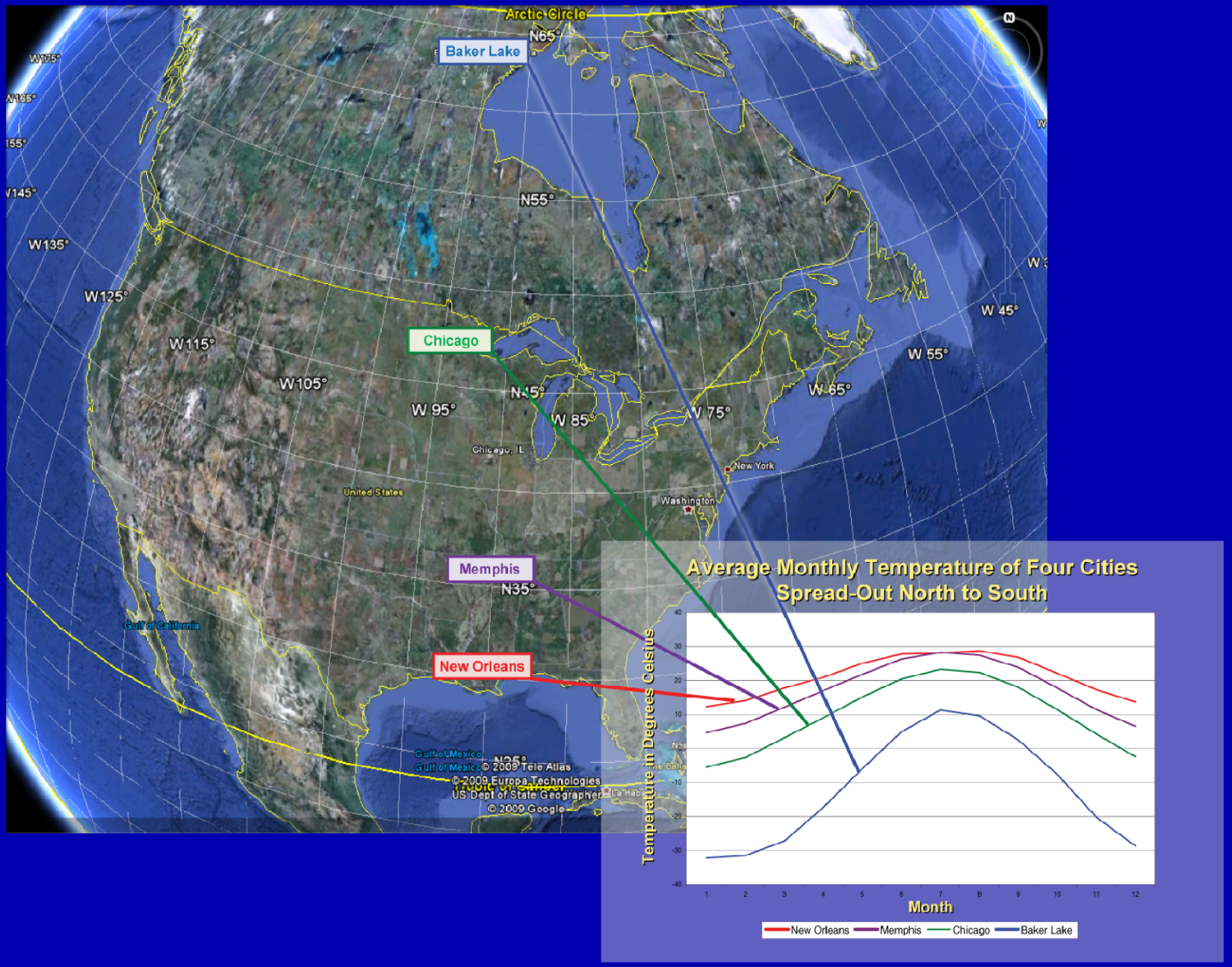
D. Sunlight warms the land directly, but the land does not warm the air and the air is not warmed directly by the sunlight.

Misconceptions Identified in Pilot Testing

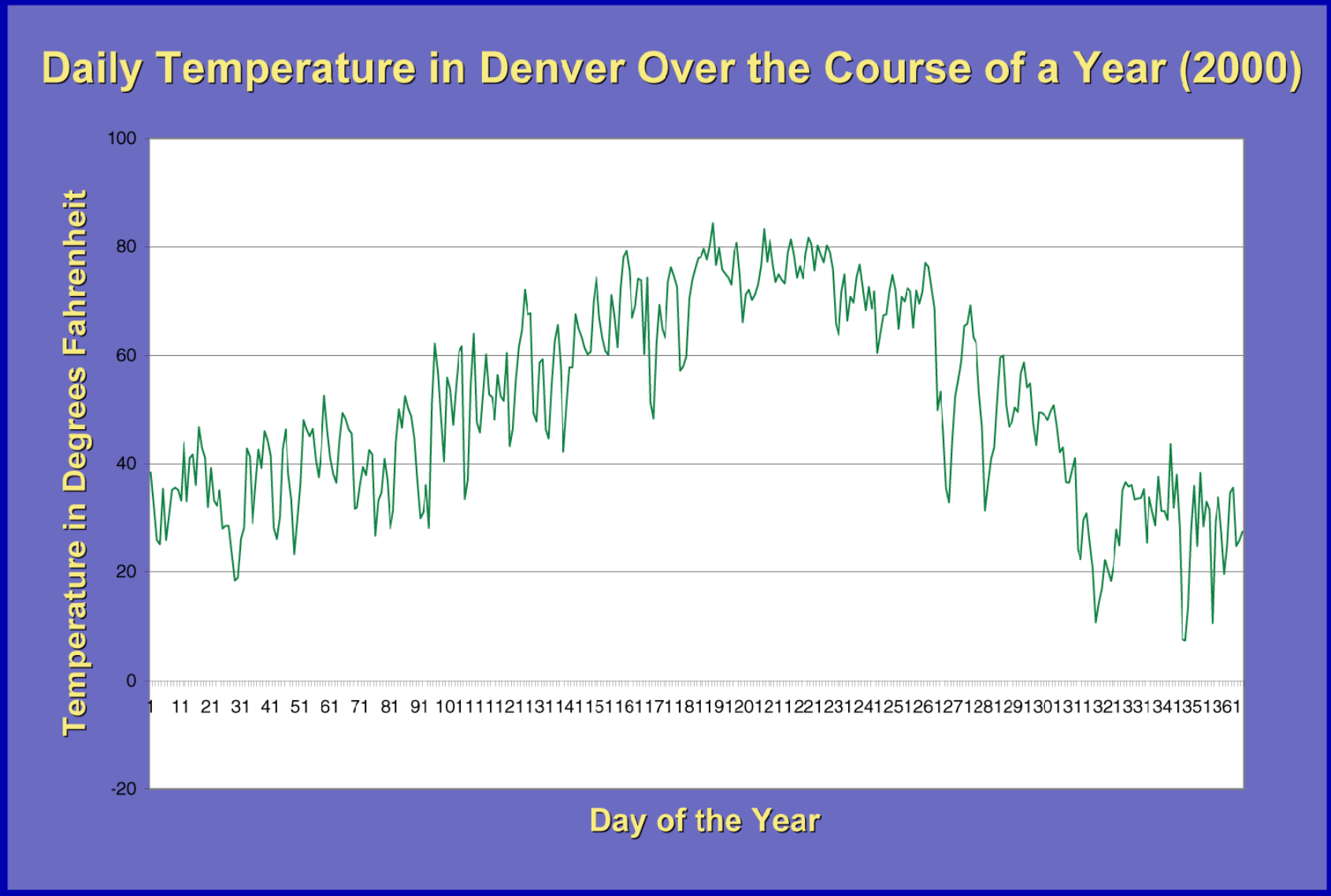
About 20% of middle and high school students chose the following responses over the correct responses:

- The air is warmed by the sun but not by the land.
- Wind blowing has nothing to do with changes in air temperature.
- As density of air increases air pressure decreases.

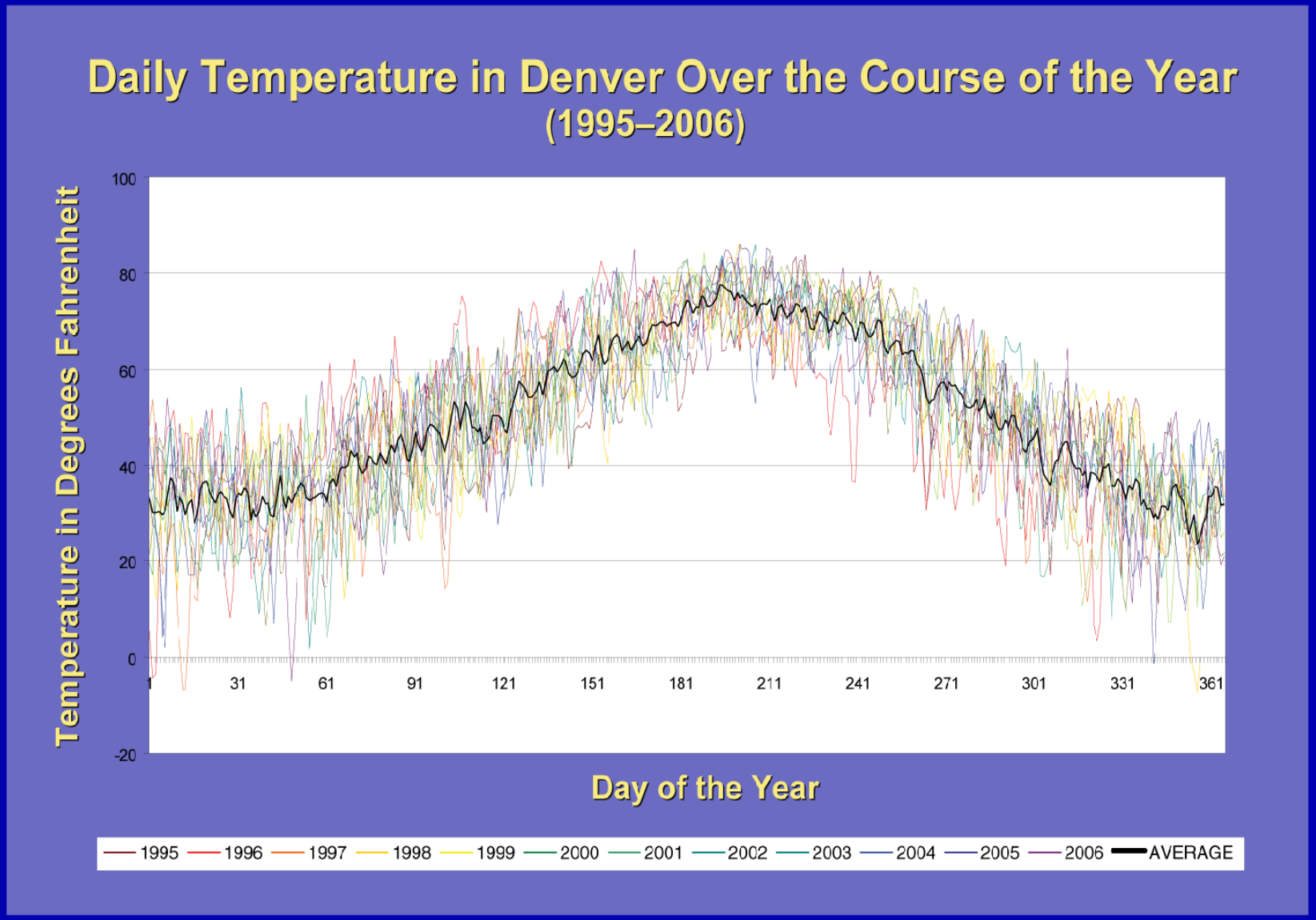
Variations in Temperature Patterns with Latitude



Temperature Variations over a Year in a Place



Average Temperature Pattern in a Place over 11 Years



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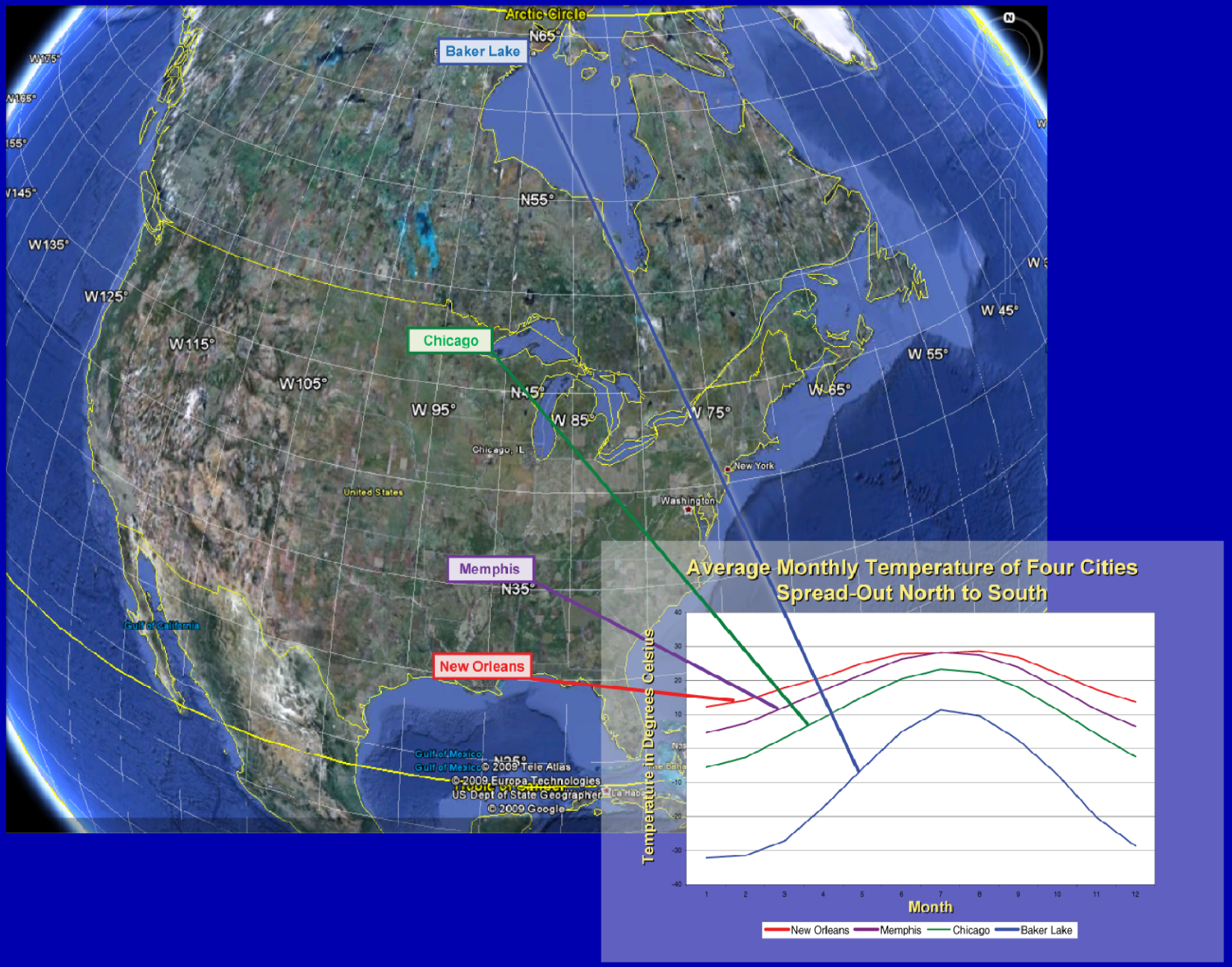

Next Steps

- Revise pilot test items for field testing
- Develop new items for subsequent pilot and field testing
- Use items to investigate the effectiveness of phenomena and representations we are identifying and designing
- Make items available for use in other studies of learning and of program effectiveness
- Expand our collaborations with groups seeking to understand and improve Climate Literacy