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K.C. Busch, MA
Jonathan Osborne, PhD
Stanford University

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You are Here…

Despite overall consensus among scientists about the negative effects of human activity on the climate, doubt has increased over the last six years within the general U.S. public. In 2006, 47% of those polled agreed there is solid evidence for human-caused global warming, while only 42% agreed in 2012 (Pew Research Center, 2012). The source for this doubt can be attributed partially to lack of knowledge about climate science. A study conducted by the Yale Project on Climate Change Communication found that 92% of U.S. citizens polled would earn a "C" or worse on their knowledge of climate change science (Leiserowitz, Smith & Marlon, 2010).

Formal, K-12 education is one mechanism which could address inadequate public understanding of climate science as school is the primary place where students (our future citizens) learn about the climate. So, are our students learning about climate science in school? The emphatic answer is "No!" In 2007, America earned a "C+" grade on how well individual states had incorporated atmosphere, weather, and climate science into their state science standards (Hoffman & Barstow, 2007).

To see what is happening, it is important to look at two states in particular: Texas and California. Texas and California are not only the largest state contributors of carbon dioxide (they are #1 and #2 respectively) (U.S.Energy Information Agency, 2012), but they also greatly influence the content found in science textbooks because of their large student populations. One might then ask, how well are these states teaching climate science to their students?

Not well, as it turns out. For both states, graduation requirements do not include Earth Science – the course where most climate science-related standards are found. Rather, most high school students from both Texas and California take the required biology course. Therefore, a typical high school graduate from Texas would only encounter science instruction on climate once, in fifth grade, when they would be asked to "differentiate between weather and climate" (see Table 1) (Texas Education Agency, 2009). A typical high school graduate from California would fare a bit better, being exposed to climate science (and we are using that term extremely loosely) on three occasions: two times during middle school science and once during high school biology (see Table 2). The Californian middle school student would learn that organisms live in different climate zones and that these climate zones are created by "movements of Earth's continental and oceanic plates through time." In high school, the same student would learn "how to analyze changes in an ecosystem resulting from changes in climate" (California State Board of Education, 1998). None of the standards for these two states include any mention of human-caused climate change. So, if "here" is the current, dismal state of climate knowledge and of the science standards guiding science instruction in our schools, then where is "there"? In other words, what exactly should a student or citizen know and understand to be considered knowledgeable about the climate?

Where is There?

In a joint effort, several governmental agencies (e.g., the National Oceanic and Atmospheric Association and the National Science Foundation), non-governmental organizations (e.g., the American Association for the Advancement of Science), scientists and educators have created a list called The Essential Principles of Climate Science Literacy. This list details seven concepts deemed vital for individuals and communities to understand Earth's climate system, the impacts of climate change, and approaches to mitigation (U.S. Global Change Research Program, 2009). Clearly, current state standards fall well short of these criteria. Only one of these standards (standard 6) is politically, though not scientifically, contentious. And with the publication of the latest IPCC report there is even more confidence of this principle. The seven principles are:

1. The Sun is the primary source of energy for Earth's climate system.
2. Climate is regulated by complex interactions among components of the Earth system.
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes.
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
6. Human activities are impacting the climate system.

7. Climate change will have consequences for the Earth system and human lives
(USGCRP, 2009, p. 9-16).

Since 2011, a 41-member writing team from 26 states has been developing and refining a new set of national science standards for K-12 education. Two rounds of public feedback were sought and then used in the revision process. This past spring, the working group released the final version of the Next Generation Science Standards (NGSS) for adoption. The NGSS is organized somewhat differently than previous national standards documents. The NGSS provides Performance Expectations, which are statements to be used for assessment of student science learning. These Performance Expectations were drawn from and are correlated to the Disciplinary Core Ideas developed by the National Research Council's *A Framework for K-12 Science Education*. The Disciplinary Core Ideas are considered the most essential ideas that a student should understand after they finish their K-12 science education. Taken together, the Performance Expectations and the Disciplinary Core Ideas outline what a student should know about science when they graduate from high school. These changes invite the question, then, are states that adopt these standards better poised to teach students about climate science? Thankfully, the answer is yes!

Not only will climate science be taught in greater quantity (more standards include climate as a topic) but also with greater quality (more clearly and richly described climate science learning outcomes). Climate is included in both the Performance Expectations (see Table 3) as well as within the Disciplinary Core Ideas (see Table 4). Climate is mentioned six times in elementary, four times in middle, and three times in high school biology. In addition, climate is included eleven times in high school earth science; however this course is generally not required for graduation. The standards are also more comprehensive and detailed in their language. Under the new standards, the same fifth grade Texas student who would have been "differentiating between weather and climate," will be expected to "develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact [Examples could include the influence of the ocean on ecosystems, landform shape, and climate]" (Achieve, Inc., 2013).

Additionally, the NGSS are more closely aligned with the seven Principles of Climate Science Literacy. Most of the principles are covered directly in the language of the standards. For example, the Next Generation standard above – "develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact" – can be linked to principles two and five, namely that the "climate is regulated by complex interactions among components of the Earth system" and that "our understanding of the climate system is improved through observations, theoretical studies, and modeling."

Can We Get There?

Clearly the Next Generation Science Standards provide more opportunity to teach and learn about climate science in the K-12 setting than do existing state science standards, so is the "there" within our grasp? The strongest impediment is that the adoption of the new standards is voluntary at the state level. So, again let us consider California and Texas.

California is one of the 26 lead-state partners and has been involved in the development and implementation of the Next Generation standards. The State Board of Education unanimously adopted them in September to replace the aging standards developed in 1998, prior to American public consciousness of the climate change issue. This bodes well for the six million California public school students.

Texas, however, does not have any intention to adopt these national standards. "We write our own standards here in Texas," stated Barbara Cargill, who is the Republican elected chairwoman of the Texas State Board of Education (Smith, 2012). If that means that Texas students will continue to get the same virtually non-existent education about climate change, then such an outcome would be extremely troubling considering Texas public schools are responsible for educating nearly one-tenth of U.S. public school students.

During the most recent revision and adoption of state science standards in 2009, the Texas State Board of Education was involved in considerable controversy over the wording for the teaching of evolution. The state board finally rested upon this contested wording: students should be "examining all sides of scientific evidence of those scientific explanations." Proponents asserted this was designed to promote the teaching and learning of "alternative theories" of evolution. Opponents argued this wording opened the door for non-science or junk science to be taught in Texas classrooms (Smith, 2012). If the statement is taken as it should be and Texas students are given the opportunity to examine the scientific evidence – which overwhelmingly supports evolution and that climate change is occurring – then we have no problem with such a standard. If the statement is used to give equal time to theories for which there is little evidence and which are not seen as credible by the scientific community, or to suggest that the topic should not be taught at all, then Texas students will be offered an inferior education. Many would argue that science, with its fundamental commitment to evidence as the basis of belief, is the epitome of rationality (Kitcher, 2001; Longino, 1990; Siegel, 1989). The function of a good science education is to present the scientific evidence and arguments so that students can understand how this view of the world has come to be. Distorting what that evidence says does a disservice to science and a disservice to any education in science.

In closing, it may be neither "here nor there" to be hopeful about increasing student knowledge regarding climate science through the adoption of the Next Generation Science Standards. At this point, climate scientists put us on track for irreversible climate change. However, while meaningful mitigation may no longer be a possibility, current K-12 students live in a world in which climate change adaptation will not only be necessary, but a part of their everyday lived experience. It is important for them to know that some of their predecessors fought for their right to understand the natural world in which they live and had the hope they might be able to fix some of the problems they have unjustly inherited.

K.C. Busch is a PhD candidate in science education at Stanford University and is currently researching how teachers and students communicate about climate change in the classroom to improve science education. She earned an MA in science education from the University of Texas in Austin and a BS in ecology from Iowa State University. She has twelve years of formal science teaching experience in secondary schools in Austin, Texas, as well as two years of informal environmental education experience in Africa with the Peace Corps and Nevada with the National Park Service.

Jonathan Osborne is the Shriram Family Professor of Science Education in the Graduate School of Education, Stanford University. He is chair of the group that developed the framework for the OECD PISA assessment of science in 2015 and was President of the National Association for Research in Science Teaching in 2006. Osborne's career started in teaching high school physics in London and after 12 years he moved to work at King's College London where he was Head of Department from 2005-2008.

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Table 1
Texas state K-12 science standards covering climate-related science

Grade	Subject	Texas Science Standards
5		Students will differentiate between weather and **climate**
HS	Earth Science	Students will evaluate heat transfer through Earth's subsystems by radiation, convection, and conduction and include its role in plate tectonics, volcanism, ocean circulation, weather, and **climate**
HS	Earth Science	Students will explain how thermal energy transfer between the ocean and atmosphere drives surface currents, thermohaline currents, and evaporation that influence **climate**
HS	Earth Science	Students will discuss mechanisms and causes such as selective absorbers, major volcanic eruptions, solar luminance, giant meteorite impacts, and human activities that result in significant changes in Earth's **climate**
HS	Earth Science	Students will evaluate the role of plate tectonics with respect to long-term global changes in Earth's subsystems such as continental buildup, glaciation, sea level fluctuations, mass extinctions, and **climate** change
HS	Earth Science	Students will describe how changing surface-ocean conditions, including El Niño-Southern Oscillation, affect global weather and **climate** patterns
HS	Earth Science	Students will investigate evidence such as ice cores, glacial striations, and fossils for **climate** variability and its use in developing computer models to explain present and predict future **climates**

Table 2
California state K-12 science standards covering climate-related science

Grade	Subject	California Science Standards
6		Students know evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and midocean ridges; and the distribution of fossils, rock types, and ancient **climatic** zones.
7		Students know how movements of Earth's continental and oceanic plates through time, with associated changes in **climate** and geographic connections, have affected the past and present distribution of organisms.
HS	Biology	Students know how to analyze changes in an ecosystem resulting from changes in **climate**, human activity, introduction of nonnative species, or changes in population size.
HS	Earth Science	Students know the differing greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the **climatic** consequences of each.
HS	Earth Science	Students know features of the ENSO (El Niño southern oscillation) cycle in terms of sea-surface and air temperature variations across the Pacific and some **climatic** results of this cycle.
HS	Earth Science	Students know weather (in the short run) and **climate** (in the long run) involve the transfer of energy into and out of the atmosphere.
HS	Earth Science	Students know the effects on **climate** of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.
HS	Earth Science	Students know how Earth's **climate** has changed over time, corresponding to changes in Earth's geography, atmospheric composition, and other factors, such as solar radiation and plate movement.
HS	Earth Science	Students know how computer models are used to predict the effects of the increase in greenhouse gases on **climate** for the planet as a whole and for specific regions.

Table 3
NGSS performance expectations covering climate-related science

Grade	Subject	NGSS Performance Expectations
3		3-ESS2-2. Obtain and combine information to describe **climates** in different regions of the world.
3		3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change. [Assessment does not include the greenhouse effect or **climate** change.]
3		3-ESS2-1. Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season. [Assessment does not include **climate** change.]
5		5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and **climate**; the influence of the atmosphere on landforms and ecosystems through weather and **climate**; and the influence of mountain ranges on winds and clouds in the atmosphere.]
MS		MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional **climates**.
HS	Life Science	HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, **climate** and competition.]
HS	Life Science	HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems(such as ranges of seasonal temperature, long-term **climate** change, acidity , light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]
HS	Earth Science	HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include **climate** feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice.]
HS	Earth Science	HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in **climate**. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.]
HS	Earth Science	HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional **climate** change and associated future impacts to Earth systems.[Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a **climate** change and its associated impacts.]
HS	Earth Science	HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in **climate** have influenced human activity. [Clarification Statement: Examples of the results of changes in **climate** that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

Table 4

NGSS Disciplinary Core Ideas covering climate-related science

Grade	Subject	Disciplinary Core Ideas
3		**Climate** describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)
5		Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences **climate**. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)
MS		Weather and **climate** are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)
MS		The ocean exerts a major influence on weather and **climate** by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6)
MS		Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of **climate** change and reducing human vulnerability to whatever **climate** changes do occur depend on the understanding of **climate** science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)
HS	Life Science	Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and **climate** change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (secondary to HS-LS2-7), (HS-LS4-6)
HS	Earth Science	Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual **climate** changes. (secondary to HS-ESS2-4)
HS	Earth Science	The geological record shows that changes to global and regional **climate** can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)
HS	Earth Science	The foundation for Earth's global **climate** systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-4) (secondary to HS-ESS2-2)
HS	Earth Science	Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect **climate**. (HS-ESS2-4)
HS	Earth Science	ESS3.D: Global **Climate** Change - Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)
HS	Earth Science	Current models predict that, although future regional **climate** changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global **climate** models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6)
HS	Earth Science	SS3.D: Global **Climate** Change - Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6)