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Implementing the NGSS

The *Framework for K-12 Science Education* (*Framework*) developed by the National Research Council and the Next Generation Science Standards (NGSS) based on them as developed by Achieve "present a vision of science and engineering learning designed to bring these subjects alive for all students, emphasizing the satisfaction of pursuing compelling questions and the joy of discovery and invention." Because of the unique three-dimensional structure of the *Framework* and Standards – science and engineering practices and crosscutting concepts as well as core ideas – implementing them will take more than the usual amount of time and effort required to institute change. Because of this, a seven-member Committee on Guidance on Implementing the Next Generation Science Standards, all of whom are present or former members of the National Research Council's Board on Science Education and chaired by the same Dr. Helen Quinn who chaired the committee who wrote the *Framework*, was charged to "write a short report regarding necessary steps toward implementation of the Next Generation Science Standards . . . . identify the parts of the education system that need to be attended to when implementing the standards and discuss the changes that need to be made to each part of the system."

Their report, *Guide to Implementing the Next Generation Science Standards*, provides seven principles to guide implementation of the Standards and 21 recommendations directed toward six aspects of education: instruction, professional development, curriculum resources, assessment, collaboration, networks and partnerships, and policies and communication. Following an introductory chapter, the principles are presented in chapter 2, and the last six chapters are devoted to the aforementioned six aspects of education. Each of these last six chapters begins with a box containing the relevant recommendations, which is followed by a general discussion and a list of "Pitfalls to Avoid."

(continued on page 12)

2015 Summit on Implementing the *NGSS* at the State Level

by Michael J. Passow, Earth Sciences Correspondent

The Center for Geoscience and Society of the American Geosciences Institute (AGI) and the National Association of Geoscience Teachers (NAGT) hosted a *Summit on Implementation of the Next Generation Science Standards (NGSS) at the State Level* from 29 April through 1 May 2015. About 60 participants, including your correspondent, representing a wide array of scientific and science education organizations, federal and state agencies dealing in Earth System Science (ESS), colleges and universities, and other formal and informal science education groups convened at NOAA Headquarters in Silver Spring, MD.

The Summit conveners were Edward Robeck of the AGI and two NAGT Past-Presidents, Aida Awad of Maine East (IL) High Science, and Susan Buhr-Sullivan of the Cooperative Institute for Research in Environmental Sciences. Supported by a National Science Foundation grant and NOAA, the Summit presented illuminating talks by many of the leaders in the creation of the *NGSS* and related documents from organizations who will be crucial to successful implementation of them. Participants interacted in small-group working sessions to begin the creation of three networks that will facilitate further action.

The main purpose of the Summit was to identify and/or devise strategies by which key players in the Earth and Space Sciences (ESS) community can work together to help states and school districts implement the *Next Gen-*

(continued on page 17)

Goldston describes Zero Knowledge Protocol

The key to effective nuclear disarmament is an effective system to verify that the retired nuclear weapons are indeed actual weapons, but without betraying any information about the design of those weapons. How to achieve this was the topic of Professor Rob Goldston's talk on "Zero-Knowledge Arms Control: Proving a Warhead is Real While Learning Nothing About It," as part of the Science on Saturday series at the Princeton Plasma Physics Laboratory (PPPL) on 28 February 2015.

Goldston, formerly Director of the PPPL but now a member of Princeton's Department of Astrophysical Sciences, likened this problem to Alice's proving to Bob that two cups have the same number of marbles without knowing how many marbles are in each cup. When a series of pairs of such cups is brought to Bob, he should randomly place one of each pair of cups into each of two buckets. If the two cups contained the same number of marbles, the weight in each bucket should be the same.

Goldston then moved on to analyzing objects with x-rays, noting that superimposing a negative x-ray atop a positive x-ray of the same object would yield a plain white screen, verifying that the negative and positive were made of the same object but without revealing anything about the object itself. This, he went on, is the basis for Zero Knowledge Protocol testing to verify the authenticity of retired nuclear warheads – except that in this case neutrons rather than x-rays are used. It uses pre-loadable non-electronic bubble detectors developed by Yale University. They must be preloadable so that they can be preloaded with the negative image and non-electronic so that no unallowed interference can be undertaken or claimed). The host nation preloads pairs of bubble detectors with negative images of the warhead and wraps them. The inspecting nation then unwraps them and exposes them to the inspected warhead. If the inspected warhead is the same as the warhead for which the host had preloaded the negative image, the result should be a blank screen.

IN THIS ISSUE

Editor's Note: Starred (*) items and the two cover stories on page 1 focus on implementing the Next Generation Science Standards (NGSS).

The TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION, INC., was founded at The New Lincoln School on 11 March 1982 by the late Irma S. Jarcho, John L. Roeder, and the late Nancy S. Van Vranken. Its purpose is to channel information on science and society education to interested readers. To this end it publishes this *Newsletter* three times a year. Thanks to funds from tax-deductible contributions, the Clearinghouse is happy to be able to offer its services for a one-time nominal charge. In order to continue offering its services for a nominal charge, it also solicits underwriting of its publications by interested corporate sponsors. All correspondence should be addressed to the editor-in-chief at 17 Honeyflower Lane, West Windsor, NJ 08550-2418 or via e-mail at <JLRoeder@aol.com>. The Clearinghouse is affiliated with the Triangle Coalition for STEM Education.

Why is there divided opinion about climate change?

by John L. Roeder

Two areas in which the findings of the majority of the science community are not shared by more than a fringe minority of the public are a) that living organisms evolved on Earth by the process of natural selection, and b) that emissions of carbon dioxide and other greenhouse gases by humans as a consequence of their lifestyle are bringing about changes in Earth's climate. In the former case the argument has been between scientists and advocates of doctrines of creationism and, more recently, intelligent design, which have been found to have no scientific basis. But in the latter case, there has been a fringe of "climate change skeptic" *scientists*, including the quartet about which Naomi Oreskes and Eric Conway wrote in their book, *Merchants of Doubt* (reviewed in our Winter 2012 issue).

Because it seems to me that all who consider themselves to be practicing scientists should play by the same "rules" of gathering, interpreting, and reaching conclusions from data, I have found it troublesome that this fringe of "climate change skeptic" scientists and the majority of scientists should constitute two opposing factions whose behavior sometimes seems reminiscent of the two major political parties in the U.S. Congress. When I received an invitation by the Princeton Area Alumni Association to attend a seminar on climate change to be given by Physics Professor Will Happer, a known climate change skeptic, I saw this as an opportunity to gain some insight into the point of view of the "opposition" and try to ascertain whether there was any basis for a *legitimate* disagreement.

The most enlightening thing I took away after attending the seminar and exchanging some subsequent e-mails with Happer is that the increase in atmospheric temperature varies logarithmically with the carbon dioxide concentration, but that there is contention about the numerical increase in atmospheric temperature when atmospheric carbon dioxide becomes twice as concentrated, a number which I subsequently learned is called "climate sensitivity." Happer provided a Wikipedia link to a formula, and a colleague provided another (temperature change in degrees Celsius = natural logarithm of ($1 + 1.2x + 0.005x^2 + 0.0000014x^3$), where x is atmospheric carbon dioxide concentration in parts per million (ppm)), but no one could provide a derivation.

Happer's colleague said that the formula would give a temperature increase of 1.2^{o}C for the climate sensitivity. Happer himself used the value of 1^{o}C, which was also that used by the MODTRAN model calculation he used in his presentation. Since then I have been in search of values of climate sensitivity and a derivation of a theoretical expression. What I found is summarized in the table on the next page.

The references to "TWTW" are to "The Week That Was," an e-newsletter from The Science and Environmental Policy Project, founded under the leadership of Fred Singer, one of the quartet described by Oreskes and Conway. Except for their accurate quotation from the 2013 IPCC report, most of their values for climate sensitivity are low.

I read the Stevens and Bony paper in *Physics Today* with special interest, because it listed two values of the temperature increase for doubled atmospheric carbon dioxide concentration – one in the presence of water and one without. Could it be, I wondered, that the climate change skeptics were using the latter value, even though the absence of water would be unrealistic, while others were using the value with water present (which is only half a degree lower than that used by IPCC and Hansen)?

Then I found the perspective in the 9 December 2011 issue of *Science*, in which Gabriele Hegerl and Tom Russon cite the work of Andreas Schmittner, *et al*., in the same issue. Schmittner and his colleagues used the University of Victoria Earth System Model to program Earth's climate back to the Last Glacial Maximum with a variety of values for the climate sensitivity to find which value most closely matched the known Earth climate at the Last Glacial Maximum. They found matches between 1.3^{o}C and 4.6^{o}C, with the best fit for 2.4^{o}C, which is not very different from the result of Manabo and Wethereld's 1964 climate model. Two thirds of the probability lay between 1.7^{o}C and 2.6^{o}C, and ninety percent between 1.4^{o}C and 2.8^{o}C.

An online link to Real Climate <www.realclimate.org/index.php/archives/2013/01/on-sensitivity-part-i/> from an article which appeared in the 14 May 2013 issue of *The New York Times* alerted me to additional determinations of climate sensitivity from matching global climate models (GCMs) to data since the Last Glacial Maximum. In volume 39 of *Geophysical Research Letters* (2012) <http://dx.doi.org/10_1029/2012GL053872>, J. C. Hargreaves, J. D. Annan, M. Yoshimori, and A. Abe-Oushi estimate climate sensitivity to be 2.5^{o}C, with high probability that it is less than 4, using the "PMIP2 multimodel ensemble of GCMs." In volume 29 of *Quartenary Science Reviews* (2010) <http://dx.doi.org/10.1016/

(continued on page 4)

climate change divisiveness

(continued from page 3)

j.quascirev.2009.09.026>, Peter Kohler, *et al.*, estimate climate sensitivity to be between 1.4°C and 5.2°C, with 2.4°C most likely.

The determination of climate sensitivity from matching of data to models suggested to me that expecting a theoretical derivation may have been in vain. Further, the explanation by Schmittner, *et al.*, and others of how they determined it would give their values greater credibility than others for which no reasons are provided.

Karen Shell's perspective on the work of John Fasullo and Kevin Trenberth in the 9 November 2012 issue of *Science* shows a different approach to determining cli-

(continued on page 20)

source	climate sensitivity
Will Happer	1°C
MODTRAN model	1°C
Lubos Motl	1.2°C
Harold Docran (TWTW, 21 Dec 13; online search for author led to no results)	1.5°C-1.6°C
Nir J. Shaviv (*Skeptical Science* website lists no peer reviewed climate change papers by Shaviv)	1°C
Berner and Kothavula's GEO CARB III model cited in Shaviv, "20th Century Global Warming: There is nothing new under the sun"	<1.5°C
Berner and Kothavula, "GEO CARB III: A Revised Model of Atmospheric CO_2	2.5°C
Chip Knappenberger and Patrick Michaels (TWTW, 22 Jun 14; *Skeptical Science* website lists six peer-reviewed papers negative on anthropogenic global warming)	3°C
Hegerl and Russon's citation of Schmittner, *et al.*, in *Science* (9 Dec 11)	2.4°C + 2.2°C, - 1.1°C
Hargreaves, Annan, Yoshimori, and Abe-Oushi, in *Geophys. Research Lett.* (2012)	2.5°C
Kohler, *et al.,* in *Quartenary Sci. Rev.* (Jan 2010)	2.4°C + 2.8°C,- 1.0 °C
Fasullo and Trenberth in *Science* (9 Nov 12)	4 °C
IPCC, 2007 (Hegerl and Russon, *op. cit.*)	3°C + 1.5°C, - 1°C
IPCC, 2013 (TWTW, 15 Mar 14)	3°C±1.5°C
James Hansen, *Storms of My Grandchildren*	3°C±1.5°C
Bjorn Stevens and Sandrine Bony, "Water in the Atmosphere," *Phys. Today*, **66** (6), 29-34 (Jul 2013)	1°C, in absence of water, 2.5°C in presence
1964 climate model by Syakuro Manabo and Richard Wethereld (Richard Layman, *American Decades (1960-1969)* (Gale Research, New York, 1995), p. 462.	2.3°C

The Road to Natural Quasicrystals

Why would a physicist better known for his theoretical work in inflationary cosmology give a talk titled "Once Upon a Time in Kamchatka"? Because that's where he ended up having to go to bring closure to his search for quasicrystals in nature.

The physicist in question is Paul Steinhardt of Princeton University, and the subtitle of his talk, presented at the Princeton Plasma Physics Laboratory on 7 March 2015, was "The Extraordinary Search for Natural Quasicrystals." And he had to go to Chukotka, the northern part of Kamchatka, which is beyond Siberia and not open to travel, even to Russians, to find them.

How he did this is a tale of adventure filled with gripping excitement. But before Steinhardt started telling his audience about his adventure, he told them what a quasicrystal is. Crystals are periodic arrangements of atoms or ions in a lattice, which look the same when they are rotated about an axis through an angle known to be an angle of symmetry. Only certain angles of symmetry are allowed – 60^o and 120^o for planes of atoms arranged from repeated regular triangles or hexagons, 90^o for planes of atoms arranged from repeated squares, and 180^o for planes of atoms arranged from repeated rectangles or parallelograms. These axes are said to possess six, three, four, and twofold symmetry, respectively.

But there are other substances, like Al_6Mn, which show themselves to have tenfold symmetry when they diffract electrons, which Steinhardt showed in one of his slides. These substances have clusters of atoms arranged in regular pentagons, but since a floor cannot be covered seamlessly with pentagonal tiles, the pentagonal clusters of atoms must alternate with clusters of atoms arranged in other regular shapes. The atomic arrangement of these substances is that of a quasicrystal, so named because it is quasiperiodic, depending on two patterns with two different periodicities. Steinhardt showed how the structure of a quasicrystal can be recognized by drawing line segments in the two patterns and assembling them so that the line segments join to form straight lines. The two patterns that he showed are related by an irrational number, the Golden Ratio, $(1 + \sqrt{5})/2$, he added. He also noted that quasicrystals can be made from two different patterns in three as well as two dimensions. For example, $Al_{63}Cu_{24}Fe_{13}$ has three-dimensional icosahedral symmetry.

Before Steinhardt's quasicrystal research, all the known quasicrystals had been made by humans. But, given human ability to make them, Steinhardt wondered whether they could exist in nature. He began his search in museum exhibits, but when he came to Princeton in 1998 he teamed with other Princeton faculty such as Ken Deffeyes in geosciences (whose *Hubbert's Peak: The Impending World Oil Shortage* was reviewed in our Spring 2005 issue). Steinhardt and his colleagues proposed a scheme to identify quasicrystals in nature, and in October 2007 Luca Bindi from Firenze responded with interest. Bindi had a sample of khatyrkite from the Koryak Mountains in Karisk, Russia, on which he had conducted an electron microprobe, showing several combinations of copper and aluminum. They submitted pulverized pieces to an electron microscope and found a tenfold diffraction pattern and all the points expected from the symmetry of a soccer ball. The composition was found to be $Al_{63}Cu_{24}Fe_{13}$. Lincoln Hollister (whose talk to the Princeton chapter of Sigma Xi was covered in our Spring 2010 issue) felt that this was impossible, since the aluminum was present as a free element, though it could have been made deep within the Earth. Glenn Macpherson of the Smithsonian also felt it was impossible to be made in a meteorite.

Bindi's sample had been purchased from a collector in Amsterdam, but establishing that it was a quasicrystal produced by nature required tracing it back from Amsterdam to its point of origin on Earth. Could it have come from the Koryak Mountains? Or could it have been slag? A search of museums on the Internet turned up four alleged samples of khatyrkite, but three of them contained no copper or aluminum and were deemed fakes. Only the sample in St. Petersburg was legitimate, but Steinhardt and his team were not allowed to conduct tests on it. Academician Razin, now moved to Israel, attested that it had been found in the ground, but he had no geological notebook to support it. Meanwhile, the widow of the collector in Amsterdam was located, and they found in her husband's secret diary the story of how he had obtained the khatyrkite from a smuggler in Romania, who could be located. A *secret* secret diary traced the origin of the Amsterdam sample to Razin, whose paper referred to Kryachko, who was traced and interviewed. Kryachko had heard of the quasicrystal story and was eager to help and verified the location of the khatyrkite's origin. It was later determined to have been formed in a carbonaceous chondrite.

Further pursuit of this story would require an impossible trip to Chukotka, Steinhardt continued. But the trip was made, on a tracked all-terrain vehicle (which could blaze its own trails), in 2011. Six weeks after returning to the U.S., the team found samples collected on the trip

(continued on page 6)

The Road to a Sustainable Energy Future

As the result of her belief that human survival on Earth requires making major science and engineering breakthroughs in the harvesting, storage, transmission, and use of energy, Emily Carter changed her research focus on the application of quantum mechanics to understand molecular and material behavior "in directions designed to help move the planet onto a sustainable energy path" and subsequently became the Founding Director of the Andlinger Center for Energy and the Environment at Princeton University. This was the basis for her talk on "Quantum Mechanics and the Future of the Planet" (subtitled "The Road to a Sustainable Energy Future") in the Science on Saturday program at the Princeton Plasma Physics Laboratory on 31 January 2015.

"The planet will not mine itself onto a sustainable path," she opened; "we have to do it." She then showed that, according to the latest Lawrence Livermore US energy flow diagram, we are still dependent on nonrenewable fossil fuels for more than 80% of our energy. Carter than outlined what she saw to be the solutions for the 21st century:

- Energy efficiency; clean hydrofracking of natural gas to replace coal; and electric vehicles in the *near-term* (although "clean" is not yet achieved, Carter believes that it can be.).
- Fuel cells; cheap, efficient solar and wind; safer nuclear; and a smart grid in the *medium-term*.
- Waste heat recovery; biofuels (from algae and microbes – Carter doesn't favor using food for biomass; the greater the percentage of biodiesel, the cleaner the burning); carbon dioxide capture and sequestration (because completely eliminating fossil fuels won't happen) in the *long-term*.
- Solar fuels; grid scale storage; superconducting transmission; nuclear fusion (which she said is suffering from lack of investment in the US) in the *longer-term*.

Carter added that we also need efficient water desalination, climate adaptation, and environmental remediation, plus appropriate economics, policy, and behavior.

She went on to describe her research portfolio: alternative photovoltaics, solid oxide fuel cells, photoelectrochemical/solar fuels, fusion reactor walls, biofuel combustion, and fuel-efficient vehicles. To pursue this, she uses computational science, because she feels that computer modeling can provide more information than the direct measurements that can be made. Her research strategy is to use quantum mechanics for energy materials design, also to assess combustion of biofuel molecules.

She cited the following challenges to sustainable energy sources:

- China's control of rare earth resources
- Intermittency of alternative energy sources
- Disintegration of fusion reactor walls (one approach is coating them with liquid lithium, which acts like a sponge for hydrogen isotopes to form lithium deuteride and results in no irreversible erosion, neutron damage, or heat overload)
- Development of alternative photovoltaics, because the energy gap in silicon makes it less than ideal
- Development of catalysts for fuel cells to allow solar energy to decompose water (although manganese oxide absorbs only ultraviolet, adding zinc reduces its bandgap to allow absorption of visible light; doping with cobalt or nickel changes the water oxidation potential)

Producing fuels from solar energy in fuel cells could provide electricity at night, thus eliminating the intermittency problem that presently limits the availability of solar photovoltaic energy. Carter noted that this is something that could be applied to individual homes.

Carter closed by sharing information about programs conducted by the Andlinger Center she directs. She was particularly proud of the Program in Technology and Society, Energy Track, the goal of which is to educate social science and humanities students about energy technology and to educate science students in the social implications of energy technology.

Quasicrystals

(continued from page 5)

that showed the same electron diffraction pattern as $Al_{63}Cu_{24}Fe_{13}$. Now the first quasicrystal known to be found in nature, though recognized to have been formed in a meteorite, it is registered under the name *icosahedrite*. The second natural quasicrystal has only one tenfold symmetry axis, like a stack of decahedral prisms.

(*Editor's Note*: The 19 March 2015 Sigma Xi Smart Brief contained a report of finding a quasicrystal on a meteorite as old as the solar system which crashed into Earth 15,000 years ago. Steinhardt is quoted as co-author of a paper published online in Scientific Reports.)

High-Adventure Science

by Amy Pallant,
The Concord Consortium

Science's greatest advances occur on the frontier, the interface between the known and the unknown. In frontier science, scientists haven't yet discovered the answers; they continue to puzzle through the data, searching for a better understanding of the world. Because frontier science is on the cutting edge, it has the potential to completely transform how we think about a topic. Earth and environmental science offer several areas for such research.

When teaching about frontier science topics such as climate change and energy usage, it's easy to gloss over the details, presenting oversimplified science or to fall back on well-worn political tropes. But Earth systems and environmental topics *are* an intricate blend of science, policy, economics, and human impacts. We must help students understand the complexities. With ongoing uncertainties with regard to climate change, energy, and freshwater availability, the focus should be on the science, presenting it as objectively as possible.

This article describes the Concord Consortium's High-Adventure Science (http://has.concord.org) free online lessons designed for middle and high school students to learn about Earth and environmental science and the effect of humans on Earth's systems. The unifying theme is the exploration of the unknown. We have developed six lessons, each lasting five class periods, that begin to unpack several big unanswered questions such as "What is the future of Earth's climate?" and "What are our energy choices?" (See all lessons on http://has.concord.org/#lessons.)

Every lesson includes interactive computer-based systems models, real-world data, and tools to help students explore evidence and discuss issues of certainty — and uncertainty — with the models and data. The design principles are explained below.

Start with the science

The High-Adventure Science strategy is to focus on teaching the science through data and models. This is important when trying to help students understand the frontier questions. Real-world data are often difficult to interpret, so we break the material down into manageable pieces, providing scaffolding for the interpretation of the evidence. We have found that approaching the topics this way makes students more likely to be receptive to the information and less likely to get overwhelmed. Students become more critical consumers of information and begin to understand the landscape on which the frontier science builds.

Use computer-based systems models

Each lesson includes a set of increasingly complex dynamic computer models that represent the particular system under study. The models have vivid graphics that engage the students. Students can change model parameters and observe the outputs, which helps them gain insights about each system and its many interacting parts. Because natural systems are complex, we guide students on how to use the models to explore the influence of a selected variable in the presence of other variables on the system. Such isolation of variables is often difficult in Earth systems.

Analyze data

Students compare the model output — and their own conclusions — to real-world data. They learn to interpret real-world data and models while considering the limitations of the models. By combining the real-world data with their own experimental data, students can look at causality, trends, and complexity in a system.

Frontier science means uncertainty

Since frontier questions have no clear-cut answers, the curriculum helps students to address uncertainty and sources of uncertainty as a key scientific practice. The High-Adventure Science project has developed a scientific argumentation item set, which addresses scientific claims and sources of uncertainty. Each argumentation item set has four prompts that ask students to 1) make a scientific claim; 2) explain the claim based on evidence; 3) express their level of certainty with the claim; and 4) describe the sources of certainty. These item sets, used throughout the curricula as well as in pre- and post-tests, encourage students to reflect on evidence from models and real-world data and to evaluate the certainty of scientific claims. We have found that students' argumentation abilities increase with the use of High-Adventure Science lessons. (See our research publications on http://has.concord.org/#about.)

The High-Adventure Science website provides access to the models, the curriculum lessons, publications, and with free registration, access to teacher guides. The lessons provide opportunities for students to enhance their understanding of cutting-edge science, including confronting the inherent unknowns and uncertainties. They

(continued on page 18)

Earth2Class Workshops for 2015

by Michael J. Passow, Earth Science Correspondent

The Earth2Class Workshops for Teachers at the Lamont-Doherty Earth Observatory of Columbia University (E2C) provide opportunities for research scientists to share cutting-edge investigations with teachers, students, and others. Many E2C workshop themes pertain to gaining greater understanding of impacts of science and technology on society. This is the first of periodic contributions summarizing information presented in these programs.

Since 1998, your correspondent has organized more than 145 E2C programs that have connected more than 80 Columbia researchers with hundreds of participants. Archived versions of past presentations are available through <www.earth2class.org/site>. The website also provide a vast array of lesson plans and slideshows, links to Standards and teacher websites, results of grant-funded projects, calendars of events, and many other resources. To learn more, explore website pages for an E2C workshop session or other information.

On 28 March 2015 Dr. Benjamin Bostick presented a workshop on "The Source and Solution to Arsenic Contamination of Groundwaters." Dr. Bostick and colleagues have spent decades investigating biogeochemical cycles involving arsenic. Arsenic is ubiquitous and a leading cause of disease in many parts of the world. The focus of Dr. Bostick's research has been in Southeast Asia, especially Vietnam and Cambodia, but arsenic is a potentially serious problem in many parts of the U.S., also. Resources from this E2C workshop are available at <http://earth2class.org/site/?p=6945>.

Worldwide, more than 2 billion people depend on groundwater for drinking and agriculture. Arsenic can dissolve in near-surface groundwaters and pose serious health threats. Even in the US, arsenic has been identified as the second-most significant cause of cancer after smoking, and a major contributor to heart disease and diabetes. Dr, Bostick and colleagues investigate the transportation of arsenic in groundwater and other sources, the origins, and interactions with organic and inorganic materials. Then, based on their findings, they try to work with scientists, engineers, and decision-makers to develop solutions for the local populations.

Vietnam and Cambodia have experienced rapid population growth in recent decades, but their natural resources have not proportionally increased. So finding ways to provide safe drinking water is a pressing issue. Unlike in other countries, such as Bangladesh, where it is possible to drill into deeper aquifers to find water with lower levels of arsenic, Cambodia can draw only from shallow sediments formed in the Holocene and Pleistocene. These aquifers tend to have much higher levels of arsenic and other pollutants.

Dr. Bostick and colleagues have worked with public health experts from these countries and Columbia University programs to try to make water safer for use. In many places, boiling is the usual approach, but this requires adequate energy sources. When possible, government water systems are expanding to replace household water sources. Agencies and experts from many countries are exploring different approaches to alternative water sources.

At present, although the problems are better understood, no short-term solutions have been found.

On 7 March 2015 Dr. Taro Takahashi presented a workshop on "Ocean Acidification and Its Effects on Marine Life." Dr. Takahashi is one of the most accomplished and respected geochemists in the world. For more than five decades, he has explored questions about carbon dioxide in the oceans and other problems. Because his work has earned many honors (http://www.ldeo.columbia.edu/news-events/five-decades-studying-co2-sea-takahashi-honored-pioneering-measurements), it was special privilege to include such a distinguished scientist to the Earth2Class Workshops.

Two key questions discussed in this presentation were the following:

1. What is the main cause of ocean acidification? What chemical reactions control ocean pH and alkalinity? What observations can be made of acidification at selected locations? What is the distribution of pH and $CaCO_3$ saturation over the global oceans?

2. What are the effects of acidification on marine organisms? How does increasing acidification affect corals and other calcifiers? What have we found through a biological study of Pacific oysters?

Using basic chemistry representation to explain methods employed worldwide to analyze sea water — many of which Dr. Takahashi pioneered — and color-coded maps to depict differences across the ocean, he provided an overview showing how data support changing patterns

(continued on page 18)

EGU General Assembly and GIFT 2015

by Michael J. Passow, Earth Science Correspondent

Each spring, the European Geosciences Union (EGU) General Assembly brings geoscientists from all over the world to Vienna for a conference covering all disciplines of the Earth, planetary and space sciences. EGU 2015, convening 12-17 April, provided a forum where scientists, especially early career researchers, could present their work and discuss their ideas with experts in all fields of geoscience. Concurrently, nearly 80 educators from around the world gathered for the 11th Geophysical Information for Teachers (GIFT) workshop of the EGU. They included, for the first time, your correspondent.

This year's GIFT workshop welcomed 76 teachers from 21 different countries. GIFT 2015 centered on the theme "Mineral Resources." Driving this selection was growing awareness that expansion of the world population from 6 to 9.6 billion in 2050 and rapid industrialization of highly populated countries, combined with an overall higher standard of living, are expected to intensify global competition for natural resources and place additional pressure on the environment, both terrestrial and marine. We recognize that mineral reserves are being depleted, and concerns are growing about access to new raw materials, especially basic and strategic minerals. Rise in the price of several essential metals, for example copper, has prompted some industrialized countries to initiate concerted activities to ensure access to strategic minerals.

Europe has recently begun initiatives that attempt to solve the issue. Europe depends greatly on imports for many materials needed for construction and heavy and high-tech industries. Recycling, resource efficiency, and searching for alternative materials are essential, but probably not sufficient to meet demands. There is a need to find new primary deposits. But politicians and business leaders are concerned because deposits, when identified, occur in areas difficult to access, barring modern exploration technology, and requiring huge investment costs. Exploration requires substantial capital, rare expertise, and leading edge technologies in order to secure the lowest extraction costs. GIFT 2015 matched teachers with experts of exploration, extraction, policy making in the field of future mineral resources, including the deep-sea frontier.

The EGU welcomed the teachers and started to bond them with a special guided visit to the Vienna Museum of Natural Sciences on Sunday, 12 April. They then joined all conference participants in the "Ice Breaker Party" at the Austria Center, where the scientific programs took place. More information about EGU 2015 is available at <http://www.egu2015.eu/home.html>.

Many of the participating teachers also contributed to the program through hands-on workshops, poster sessions, and other activities. Your correspondent presented in one of the hands-on workshop sessions classroom-based activities about minerals. Participants made models of the silicon-oxygen tetrahedron and other molecules using raisins and toothpicks. They shared strategies to teach important minerals properties, such as cleavage and magnetism, in their countries. An anticipated highlight was distributing samples of fluorescent minerals donated by the Sterling Hill Mining Museum in Ogdensburg, NJ, and watching them glow under ultraviolet energy.

Many of the teachers received partial conference expenses through professional societies and other sources. When participants return to their home countries, they are expected to complete an evaluation form to assess this year's program and provide guidance for next year's. Each will also make presentations about their EGU experience to teaching colleagues, submit reports and photographs about how GIFT information and resources have been used, and, contribute articles about the GIFT workshop to professional publications aimed at geosciences teachers.

You can learn about past GIFT workshops through the EGU website: <http://www.egu.eu/media-outreach/gift/gift-workshops.html>. Beginning in 2009, EGU has created web-TV presentations, which may be freely downloaded and used in classrooms. To expand the impact and outreach of the programs, the EGU Committee on Education began in 2012 a series of GIFT Distinguished Lectures in several European countries. Leading scientists who have participated as speakers in GIFT workshops during the EGU General Assemblies are supported to provide organized educational events for high school science teachers.

Similar GIFT Workshops are offered at the annual American Geoscience Union meetings held each fall in San Francisco. These are organized by the National Earth Science Teachers Association and the AGU Education Program. Resources from the previous four AGU GIFT workshops are available at <http://www.windows2universe.org/teacher_resources/AGU-NESTA_GIFT_Workshop.html>.

NJAAAPT addresses NGSS and AP Physics

The title and focus of the 14 March 2015 meeting of the New Jersey Section of the American Association of Physics Teachers (NJAAPT) at Princeton University was "New Standards in Physics Education." Special emphasis was given by the three featured speakers to the Next Generation Science Standards (NGSS) and the new AP Physics 1 and 2 courses.

The first speaker, Suzanne White Brahmia, director of the Extended Physics program and the associate director for physics of the Math and Science Learning Center at Rutgers University, spoke on "NGSS, the New AP, and CCSS-Math: An Opportunity for Students to Develop Physicists' Ways of Thinking." She began by observing that physics teaching is being affected by not only the NGSS but also the replacement of AP Physics B by AP Physics 1 and 2 and the CCSS-Math (Common Core State Standards in mathematics). After asking two rhetorical questions – "What is college readiness in physics?" and "Why is physics required in college?" – she revealed that polling showed the goal of physics education not to be solving problems in physics textbooks but *thinking like expert physicists*. This involves experimentation – as a way of creating knowledge – and mathematization – as a way of thinking.

Brahmia elaborated on what she meant by mathematization: it is not using lots of formulas or devices like the triangle in which three related variables are placed with one covered to show how it can be calculated from the other two. Rather, it involved physics habits of mind, which Brahmia distinguished from mathematical habits of mind: physicists, she said, use mathematics but are not mathematicians. Unlike mathematicians, physicists use units, interpret symbols in context, need to distinguish constants from variables, and group symbols to make meaning. Linearization and proportional reasoning are basic, and mathematics teaching is not always seen to impart these abilities. But, she added, physics has an advantage in the NGSS in that their crosscutting concepts are things that physicists relate to, so implementing the NGSS helps students think like physicists.

Brahmia then sought to relate the three components of the title of her talk. She noted that the new AP Physics 1 and 2 syllabi are based on seven practices and that the NGSS and CCSS-Math are each based on eight practices. She laid out these 25 practices and then regrouped them into four clusters – one on experimentation, the other three on mathematization: 1) reasoning mathematically with fundamental quantities, 2) reasoning with mathematical models, and 3) reasoning based on mathematical structure. When guided by these practices, physics is well situated, Brahmia noted, to ask students to use the math they have learned in a creative way. Learning physics, she added, is not mastering physics problems but using physics concepts to address new situations. She cited the philosophy of Eugenia Etkina's Investigative Science Learning Environment (ISLE), which is learning by doing what physicists do when they do physics – making observations, using them to develop models, and giving explanations in terms of these models. She noted that Physics Union Mathematics (PUM) is built on this to foster mathematization.

Brahmia closed with a quotation from Plutarch – "Education is not the filling of a pail but the lighting of a fire." – and an observation that student texting is an excellent example of ways for students to use symbols, also to develop their own symbols (which is found to make the processing of symbols more meaningful).

The second speaker, Coleen Weiss-Magasic, science teacher at West Milford High School, spoke on "Tackling the NGSS," and began by pointing out that a standard is something to tell you what's important and what your curriculum should look like. The NGSS, she noted, have three components: core ideas, crosscutting concepts, and practices. Meeting them is specified by performance expectations, which are accompanied by assessment boundaries (which often exclude rote memorization) and clarification statements. She went on to observe that the NGSS focus on big ideas that have broad importance, developed with increasing sophistication, taught in connection to the real world. This, she said, is made clear by the science and engineering practices and crosscutting concepts. But she advised us not to try to connect them to our current curriculum. Harmonizing new curricula with the NGSS will take time.

Weiss-Magasic went on to list online resources for "Tackling the NGSS," the first of which was the NGSS website, <www.nextgenscience.org>, which has interactivity that facilitates use of the standards. The National Science Teachers Association (NSTA) has its own website, <standards.nsta.org>, which shows the progression of core ideas through grade levels. In addition, <www.state.nj.us/education/modelcurriculum/sci> provides model curricula for New Jersey, and <learningcenter.nsta.org> provides links to NGSS webinars. Links to all the online resources cited by Weiss-Magasic are available from the NJAAPT website, <www.njaapt.org>.

(continued on page 11)

NJAAAPT

(continued from page 10)

Weiss-Magasic concluded by observing that the successful student of the future will be the thinker and the builder rather than the memorizer. It is important, she said, for students to be able to think, process, justify, and explain. Brahmia then interjected that the paradigm shift wrought by the NGSS should also apply to college teaching.

The third speaker, Robert Goodman, began his talk on “PSI Physics + NGSS = STEM Pathways for All Students” by tracing the steps which led him to his present position as executive director of the New Jersey Center for Teaching and Learning (NJCTL) and teacher of science and engineering at the Bergen County Technical High School. He “discovered” physics not until college, later got a degree in it, and went into teaching in 1999, only after a career in the electronics business. His first teaching assignment was a two hour per day math and science course for ninth graders, for which he allocated 40 minutes per day to physics, 40 to algebra, and 40 to engineering. He found that available algebra-based physics texts weren’t mathematically rigorous, so he wrote his own, one that would prepare students for the AP Physics B course and chemistry. Left to scrounge for his own physical resources in an empty room with only computer connections, he experienced a “lucky break” in commandeering a group of round tables – because he found that students learned well sitting around them talking with each other and building their own mental models. By 2003 all ninth graders were taking Goodman’s physics course. This in turn led to recognition for him and establishment of the New Jersey Center for Teaching and Learning and reversing the order of high school science courses (which had been biology, chemistry, and physics – he observed that biology doesn’t give students experience with algebra).

Thus was born the Progressive Science Initiative (PSI), in which the ninth grade physics course is followed with AP Physics 1 along with chemistry in the tenth grade, followed by biology and AP Chemistry in the eleventh. Goodman introduces each topic in his course with short direct instruction presentations with interactive whiteboards (open inquiry doesn’t allow students to sample enough content, he said), then follows them with social constructivism (students working together around the round tables). He depends on the quickest-learning students to teach the slower ones. Students like to struggle to win, he observed. “If there’s no struggle, it’s boring; if there’s no win, it’s frustrating.” PSI, Goodman went on, has shown that all students and teachers can learn physics. Goodman’s approach to providing the additional physics teachers needed by the expansion of his program is to train teachers to teach physics rather than teach physicists to teach physics, an approach which enabled him to be the largest U.S. producer of physics teachers – 1430 teachers in 218 schools.

Goodman advertised his website – <www.njctl.org> – for its more than 100,000 slides in PowerPoint presentations and upwards of 3500 editable Word documents, which he encourages teachers to use (without charge) to develop their own curricula rather than starting from scratch from the NGSS. By 2007 they were used in over 100 New Jersey schools, and they are now being used worldwide. Among New Jersey’s top performing schools, those using PSI materials have a much greater percentage of Black and Hispanic students, an indicator that PSI materials are especially effective with these groups. PSI fosters active rather than passive learning (it is not for factual recall, sitting quietly, transcribing, and accepting but rather for critical thinking, problem solving, and questioning).

Goodman concluded his presentation with critiques of the NGSS, which he regards to be the CCSS for science. The critics he cited were the American Association of Physics Teachers (AAPT) and the Thomas Fordham Foundation, both of which faulted the NGSS for not preparing students for STEM careers. But Goodman also noted that this was something recognized by the NGSS, which “recommended that students, especially those considering careers in a STEM-related field, would go beyond these courses to take science, technology, engineering, and mathematics courses that would enhance their preparation.” Two other similarly-related criticisms were Fordham’s objection to the avoidance of mathematics and AAPT’s wishing that the NGSS used more quantitative methods. Additionally, the Fordham Foundation criticized the NGSS for letting emphasis on science and engineering practices de-emphasize the importance of content knowledge.

Goodman rejoined that PSI responds to most of these criticisms by coupling physics with math. He went on to point out that, because of its fundamental nature and relationship to mathematics, physics has a uniquely important role in the preparation for STEM careers; it “makes science make sense” and “provides a use for math.” He would like to develop a K-12 integrated Physics-CCSS thread. Not all students need pursue a STEM career path, he said, but all students need to have the opportunity to choose a STEM career path. “Using physics to connect CCSS and NGSS would provide all students that opportunity.”

(continued on page 18)

Implementing NGSS

(continued from page 1)

The Introduction sets the tone of the report with a comparison between current science education and the vision of the *Framework* and the NGSS that is reminiscent of the comparison of things requiring less emphasis and more emphasis when the National Science Education Standards were published in 1996 (see our Winter 1996 issue for sample charts):

current	vision of *Framework* and NGSS
rote memorization of facts and terminology	facts and terminology learned as needed to develop explanation and design solutions based on evidence and reasoning
learning of ideas disconnected from questions about phenomena	systems thinking and modeling to explain phenomena and provide context
teachers providing information	students investigating, discussing, and solving problems with
teachers posing "right answer" ques-	students discussing open-ended questions in terms of evidence
students reading textbooks and answering end-of-chapter questions	students reading multiple sources, including magazines and journals and websites
"cook-book" labs or activities	multiple investigations driven by student questions leading to
worksheets	student writing that explains and argues
oversimplification for less able students	support enabling all students to participate

The seven principles for implementing the NGSS presented in the second chapter are as follows:

1. *"Ensure coherence across levels,. . . grades, and . . . different components of the system. . . ."*

This coherence must be *developmental* (sequenced across grade levels), *horizontal* (from curriculum to instruction to assessment, and *vertical* (from classroom to school to district to state). Implementing these coherences requires collaborative planning.

2. *"Attend to what is unique about science."*

Implementing science standards is different from implementing standards in English/Language Arts and mathematics because of the requirement of materials, laboratory space, and extended time, but it must be mindful of implementing standards in these other disciplines. Achieving additional time for science education may require integrating it with time spent on mathematics and/or English/Language Arts, given that a goal of standards in all three disciplines is productive discourse.

3. *"Develop and provide continuing support for leadership in science. . . ."*

Identifying teachers, administrators, and/or community members who are "ahead of the curve" in understanding the NGSS can establish leadership for implementing them.

4. *"Build and leverage networks, partnerships, and collaborations."*

Making implementation of the NGSS a shared experience for many will allow them to make a significant impact on science education. That many are seeking to implement the same standards also insures that all are aware of a common goal toward which they can mutually support each other to achieve.

5. *"Take enough time to 'implement well.'"*

Implementing the NGSS will increase the complexity of science teaching and thus will require sufficient time – for teachers to be trained and for new curriculum materi-

(continued on page 13)

Implementing NGSS

(continued from page 12)

als and assessments to be developed. A minimum of three to four years is estimated.

6. *"Make equity a priority."*

Both the *Framework* and the NGSS address the importance of attending to sources of inequity that would prevent access to "high-quality learning opportunities" for *all* students. Two sources of inequity need to be addressed: 1) inequity of opportunity because of inequities among schools, and 2) lack of inclusiveness in classroom activities.

7. *"Ensure that communication is ongoing and relevant."*

Implementing the NGSS at the district and state level will take longer than within a given school – an estimated five to ten years. Making this transition smoothly will require effective communication among all stakeholders.

Recommendations for Instruction:

1. "Communicate and support a vision of instruction that is consistent with *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* and *Next Generation Science Standards*."

Engaging "in scientific inquiry and engineering design . . . helps students understand how scientific knowledge develops and gives them an appreciation of the wide range of approaches that are used by scientists to investigate, model, and explain phenomena in the natural world and in engineered systems." (p. 3-3) Appreciation of definitions and facts should come from investigations, development of models, and explanations rather than the other way around. Ideas learned in a meaningful context are likely to be retained longer than those transmitted as factual information. Learning is more motivated when the ideas to be learned have significance for making sense of the world.

2. "Support teachers in making incremental and continuing changes to improve instruction."

What is meant by instruction is not information transmittal but rather "activities and experiences that teachers organize . . . for students to learn what is expected of them." (p. 3-1) There is no single way to do this. Drawing from the *Framework* and NGSS, teachers and school leaders need "to establish a shared vision of what should be happening in science classrooms" and what constitutes successful performance. About two to three years could be needed to implement the NGSS, and budgets must support new equipment needed for this implementation.

3. "Develop a classroom culture that supports the new vision of science education."

Changes will be needed in the classroom activities that students do, how they work together and interact with each other and with their teacher. Both individual and collaborative efforts will need to be supported. The reasoning and arguing from evidence that are instrumental in meeting the Common Core State Standards (CCSS) in English/Language Arts and mathematics also will play an important role in implementing the NGSS.

4. "Make assessment part of instruction."

"Classroom-based assessment activities are critical supports for instruction" because of the role they play in "students' learning experiences and inform[ing] subsequent instructional choices, while also providing evidence of progress . . . ." (p. 3-7) This is especially true of formative assessments. In addition, "science and engineering practices lend themselves well to being used as assessment activities." (p. 3-7) "Students need guidance about what is expected of them, opportunities to reflect on their performance, and detailed feedback on how to improve their performance." (p. 3-7)

Pitfalls to Avoid:

"Providing Insufficient Support for Students": Students will need "scaffolding" to do the more sophisticated things the NGSS expect of them.

"Focusing Exclusively on the 'Right Answer'": "It can be difficult to allow students to explore incorrect or partially correct ideas out of concern that they will never arrive at the correct explanation." (p. 3-8) "Students who have experienced success in school primarily by memorizing and reproducing facts or rote procedures provided to them by textbooks or teachers may resist the shift to a classroom culture where they are asked to apply science ideas and take part of the responsibility for the struggle to develop shared explanations to make sense of phenomena." (p. 3-8) Teachers should not slip into the mode of "purveyors of 'right' answers." (p. 3-9)

"Assigning Unproductive Student Tasks": Memorizing vocabulary or facts is "not consistent with the vision for learning in the *Framework* and NGSS." (p. 3-9) Instead, students should be asked to apply factual knowledge to explanations or arguments.

"Expecting Instruction to Change Overnight": Teachers need to understand the changes expected by the NGSS

(continued on page 14)

Implementing NGSS

(continued from page 13)

before they can implement them. They are expected to need from two to three years of professional development before this will happen, and even after that ongoing support will be needed.

<u>"Expecting Teachers to Do It Alone"</u>: Implementing the NGSS must be a collaborative effort of all teachers, not the result of each teacher working alone. This collaboration allows those who show more leadership and expertise to benefit all and doesn't allow anyone to lag behind while minimizing the burden on all.

<u>"Being Reluctant to Let Go of Familiar Units or Favorite Activities"</u>: No matter how "good" an activity is, if it doesn't implement the NGSS, it's got to go!

<u>Recommendations for Teacher and Leader Learning</u>:

5. "Begin with leadership."

Because leadership is necessary to make the changes needed to implement the NGSS, it is important to identify teachers and administrators who show this kind of leadership. They also need administrative support and authority, resources, and time to carry out an implementation plan. For elementary teachers responsible for the CCSS in English/Language Arts and mathematics, professional development leading to implementation of the NGSS needs to be mindful of the relationship of this implementation to that of the CCSS. After schools are well on their way to implementing the NGSS, teachers can maintain the changes they have made to their teaching through learning communities.

6. "Develop comprehensive, multilayer plans to support teachers' and administrators' learning."

7. "Base design of professional development on the best available evidence."

Studies "show that professional development focused on students' thinking and analysis of instruction is more effective than professional development focused only on improving teachers' content knowledge in science." (p. 4-3) "Professional learning opportunities should be designed such that teachers grapple with both the science itself and how students think and learn about that science." (p. 4-3) "In the NGSS, content includes all three dimensions: practices, crosscutting concepts, and disciplinary core ideas." (p. 4-3) Professional development needs to address the practices appropriate to each teacher's level and thus be different for teachers at the elementary, middle, and high school and mindful of the fact that elementary teachers also teach English/ Language Arts and mathematics. Professional development also needs to engage teachers in solving actual problems, also reflecting on both how they dealt with them and how their students might respond to them. Teachers need to do this collaboratively, because it will help create a collaborative culture to be modeled for students and invest teachers more thoroughly in the NGSS as a common goal to be implemented. Sufficient time needs to be devoted to this professional development as well – summer workshops measured in *weeks*, with follow-up sessions during the academic year are recommended. Administrators need the same professional development as teachers so that they can work with teachers and be sensitive to their needs.

8. "Leverage networks and partners." [See Principle #4 above and Recommendations 16 and 17 below.]

<u>Pitfalls to Avoid</u>:

<u>"Underestimating the Shift Needed in One's Own Practice"</u>: Fully incorporating the engineering practices mandated by the NGSS requires more than traditional egg-drop or bridge projects.

<u>"Underestimating the Need for Ongoing Support"</u>: "Teachers need . . . ongoing reinforcement to support the effort it takes to change both their own teaching practice and their classroom culture." (p. 4-6) This support can take the form of professional development, mentoring, or professional learning communities.

<u>"Failing to Provide Opportunities for Administration to Learn About the NGSS"</u>: Administrators need to learn about the NGSS, because they need to understand what is required of their teachers in order to understand what is to be expected from them.

<u>"Offering 'One Size Fits All' Learning Opportunities"</u>: Teachers with different backgrounds or teaching at different levels have different professional development needs and should be offered them, perhaps from a menu of choices.

<u>Recommendations for Curriculum Materials</u>:

9. "Do not rush to completely replace all curriculum materials."

There are no present curriculum materials expressly developed for the NGSS, and designing a curriculum that engages students in science and engineering practices and asks them to use crosscutting concepts to understand disciplinary core ideas is not a job for one standard textbook

(continued on page 15)

Implementing NGSS

(continued from page 14)

writer. Rather, a "multiyear, multi-expert team process . . . to include experts in science, science learning, assessment design, equity and diversity, and science teaching each at the appropriate grade level" is called for. (p. 5-3) Collaboration on curriculum development, especially in conjunction with a curriculum development expert, is very effective as professional development.

10. "Decide on course scope and sequencing."

Standards define the outcomes expected for students from the curriculum developed to achieve them. For the NGSS, these are the performance expectations. A curriculum needs to sequence topics and activities so that students can build coherent learning progressions from them. Courses must also be sequenced appropriately. Strategies for doing this are outlined in Appendix K of the NGSS.

11. "Be critical consumers of new curriculum materials."

Before adopting new curriculum materials, states or districts need to develop a scope and sequence of topics that reflects the goals of the *Framework* and the NGSS.

12. "Attend to coherence in the curriculum." [See Principle #1 above.]

Pitfalls to Avoid:

"Asking 'Which Standard Are You Teaching Today?'": Because the Standards are so integrated, especially their three dimensions, teaching them piecemeal "would lead to redundancies and fragmented learning." (p. 5-5)

"Waiting Before Beginning to Change Instruction": Although new teaching materials designed to meet the NGSS will not be immediately available, teachers should nonetheless try out the approaches mandated by the NGSS so they will be better able to evaluate new materials that are designed to implement them.

"Failing to Provide Resources to Support Student Investigations and Design Products": Space and equipment must be provided for student laboratory work.

Recommendations for Assessment:

13. "Create a new system of science assessment and monitoring."

14. "Help teachers develop appropriate formative assessment strategies."

New assessments must differ from current assessments by a) including "multiple components that reflect the connected use of different scientific practices in the context of interconnected disciplinary ideas and crosscutting concepts" (p. 6-1), b) identifying "where students fall on a continuum between expected beginning and ending points" (p. 6-2), and c) including a system for interpretive evaluation of a range of student products "and, for formative assessment, provide tools that can help teachers decide on next steps in instruction." (p. 6-2) Assessments must be designed to both "support classroom instruction" and "monitor science learning on a broader scale." (p. 6-2) For the former, formative tasks must be included; for the latter, summative tasks are needed: "formative tasks are those that are specifically designed to be used to guide instructional decision making and lesson planning; summative tasks are those that are specifically designed to assign student grades." (p. 6-2) Some of the summative assessments will need to be performance-based, but more will be needed to assess a year's work than the time for a state standardized test will allow. Therefore, "classroom-embedded" assessments should supplement state tests; they could take the form of portfolios. That science teaching actually follows the NGSS should also be monitored.

Because it must address practices and crosscutting ideas as well as core ideas, the assessment system envisioned by the *Framework* will be arrived at only after a long process, which must be done systematically. While this transition to assessing a whole year's work is being developed, individual teachers should experiment in their classrooms with assessments in the spirit of the NGSS for individual curriculum units. Because of the complexity of developing the new assessment system, states may want to partner with each other in developing it.

Pitfalls to Avoid:

"Failing to Differentiate the Purposes of Assessment": The following purposes for assessment must be distinguished: a) "diagnose student needs near the beginning of a unit," b) "monitor progress along the way," c) "find out how students are thinking about a topic" to "determine how best to support student learning," d) "assign grades," and e) "determine the effectiveness of a given unit."

"Failing to Respond to Assessment Results": Assessment data collection takes time away from learning, so it should not be gathered if it is not to be used, and whatever action is to be taken from it should not be delayed.

(continued on page 16)

Implementing NGSS

(continued from page 15)

"Using Old Assessments While Mandating New Instructional Methods": Changes in teaching and assessment envisioned by the NGSS will not occur abruptly, but changes in teaching and assessment should keep pace with each other.

Recommendations for Collaboration, Networks, and Partnerships:

15. "Create opportunities for collaboration."

Implementing the NGSS is a major undertaking. With many teachers and educational leaders facing the same task, they can more easily accomplish it by collaborating – within their school or district or among schools or districts – than by working alone.

16. "Identify, participate in, and build networks."

Collaboration among teachers that is generated by the teachers themselves has been found to be more effective than that which is generated "top down" from educational leadership.

17. "Cultivate partnerships."

Potential collaborators outside the school system for implementing the NGSS include 1) informal learning centers, 2) outside of school learning programs, 3) higher education institutions, and 4) business and industry. Outside organizations are also needed to document and evaluate the implementation process.

The success of a partnership requires agreement among the partners about the goal to be achieved, which in this case is implementation of the NGSS. Hidden agendas among the partners must not be allowed to interfere with this.

Pitfalls to Avoid:

"Lacking a Common Understanding of the Vision": When collaborators don't share the same understanding of the vision they are working toward, their efforts could find themselves at odds with each other.

"Having Competing Goals Among Partners": If partners have different goals, their partnership is destined for discord.

"Failing to Clarify Responsibilities and Monitor Partnerships": Discordant partnerships can be avoided by ratifying a written agreement which contains not only an agreed-upon statement of goals but also a statement of expectations of each partnership and provision for monitoring the effectiveness of the partnership.

"Failing to Establish Respectful Relationships and Roles": A viable partnership requires mutual respect of partners and the expertise that each brings to the partnership's purpose.

Recommendations for Policy and Communication:

18. "Ensure existing state and local policies are consistent with the goals for implementing the Next Generation Science Standards."

State education leaders need to make sure that their overall policies are consistent with the NGSS.

19. "Create realistic timelines and monitor progress."

Mapping the NGSS over the high school years leads to "three demanding courses with high expectations for student learning," and this is the minimum achievement for all students, so systems will need to provide more than three years for students taking more advanced courses if they are not already doing so. At the elementary level, too, adequate time must be provided for learning science. Competition for time between science and English/ Language Arts can be handled by efforts that enhance both language and scientific literacy.

20. "Use *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* and Next Generation Science Standards to drive teacher preparation."

Science teacher preparation programs will need to be "adjusted to better prepare teachers for supporting the NGSS" (p. 8-3) and "require redesigning both science and science teaching methods courses." (p. 8-3)

21. "Communicate with local stakeholders."

District and state educational leaders need to communicate to parents and the community the scope and benefits of the NGSS and the amount of time and effort needed to implement them. They also need to support teachers in responding to "parents or others who object to the inclusion in the curriculum of such topics as evolution or the human role in current global climate." (p. 8-9)

Pitfalls to Avoid

"Assuming Existing Policies Are Adequate to Support the NGSS": State, district, and school policies must be examined to insure that they can support implementation

(continued on page 18)

2015 Summit

(continued from page 1)

eration Science Standards and the *Framework for K-12 Science Education*. Specific goals included

- Identification of the needs of teachers, curriculum supervisors, local and state agencies, and others with respect to implementation.
- Establishment of an effective action network of stakeholders not only to provide communication and support among K-12 Earth and space science educators but also to include the broader geoscience community, linking network resources to identified needs.
- Assembly of a virtual catalog and collection of *NGSS*-congruent Earth and space science educational resources and development of concrete guidance for using these resources to translate the vision and structure of the *NGSS* into teaching and learning practice.

After welcoming remarks by Patrick Leahy of the AGI, Cathy Manduca of NAGT, Louisa Koch of NOAA, and the three conveners, Michael Wysession of Washington University in St. Louis, one of the Earth Science leaders in creating both the *Framework* and the *NGSS*, gave the keynote address. His talk, "The Intent of *NGSS* in ESS – The Ideal Vision," and other resources from this conference are available at <http://nagt.org/nagt/profdev/workshops/ngss_summit/2015/program.html.> Stimulated by this talk and their own expertise, participants then divided into small working groups to prioritize identified needs of the ESS community. Summaries of their reports are available on the website cited above; however, some of these resources may be password-protected until conference reports are published.

Stephen Pruitt of Achieve, Inc. described the "Many Facets of a Change Initiative" to explain more of the process by which the *NGSS* were developed, and especially *what the NGSS are and what the NGSS are not*. The focus of the breakout session following his talk on "Asset Analysis" enabled everyone to become more familiar with the abilities and connections of fellow participants.

The second day featured roundtable discussions dealing with State- and District-level planning and teacher readiness. Heidi Schweingruber of the National Academy of Science, the organization that oversaw development of the *Framework*, presented her thoughts about "Implementing Standards in a Complex System." Tamara Ledley provided an example of a successful ESS collaborative project, the CLEAN collection of resources for climate literacy. The day ended with another breakout session focused on short- and long-term goals for stakeholder groups.

Highlights of the third and final day included individual and small-group work to make plans for "How Is Next Monday Different from Last Monday"; a plenary session with David Evans of the NSTA discussing how the ESS Community can participate in NSTA initiatives to support *NGSS* implementation; and developing first steps for carrying forward as we disperse.

Professor Wysession emphasized that teacher preparation and readiness are the most important factors for successful implementation of the *NGSS* and deserve serious attention for all interested professional organization and other players. Suitable educational resources will probably be one of the biggest choke-points. Developing these requires collective impact, sharing ideas and models, and coordination from the larger community, which will necessitate a network or networks. Classroom teachers must be included in the process, but many require enhanced understanding of subject matter.

Pruitt described both the process by which the *NGSS* were developed by Achieve, Inc., along with limitations on what they can do. He suggested that the ESS Community develop advocacy strategies to support "good" science; support networks to improve teacher quality and knowledge; and avoid focusing on "assessment," because this term means different things to different stakeholders. He also responded to questions about how the *NGSS* related to what is included in IB programs and curricula in other countries where most of these concepts are taught through Physical Geography courses.

Schweingruber discussed the importance of working through the complexity of developing implementation strategies in an education system focused on K – 12 years and a political system focused on the next election. Better education for decision-makers about the potential benefits of the *NGSS* is crucial, as will be bringing in colleges and universities. Along with other speakers, she emphasized that the *NGSS* are an effort to provide "All Sciences for All Children."

Wilson addressed the prominence of ESS in the *NGSS* in connection with a call for interdisciplinary breadth. The biology, chemistry, and physics communities have been developing resources and infrastructure for decades. The ESS community can build partnerships across all disciplines to create teaching resources through collaborations from many groups.

(continued on page 18)

Implementing NGSS

(continued from page 16)

of the NGSS and the modification of teacher preparation programs to meet NGSS requirements.

"Failing to Communicate with Parents and the Community": Enlisting the community and parents as stakeholders in implementing the NGSS will help the implementation go smoother if any mishaps occur.

"Being Unprepared for Unintended Consequences": Changes can always lead to unintended consequences, and we must monitor to detect when they occur and respond to them.

"Assigning Responsibility with Authority or Resources": Responsibility requires authority and resources needed to achieve it.

The complete report is available online at <http://www.nap.edu/openbook.php?record_id=18802>.

Earth2Class

(continued from page 8)

over time-series in such variables as global temperature, pH, CO_2 levels, degree of saturation of calcite and aragonite, and other factors. Dr. Takahashi explained why certain sections of the ocean have received special attention, particularly the Drake Passage between South America and Antarctica and the waters near Iceland.

Turning to the effects on marine organisms, what is known is that changes in hydrogen ion concentration have impacts on photosynthesis, respiration, calcification, and oxidation/decomposition. But Dr. Takahashi explained that biological complexity and confusions in chemical controls of biological experiments make results of studies controversial. Reefs in some areas are thriving, while those in other locations are seriously stressed. Much progress has been made in understanding the problems, but much still remains to be done.

You can learn more exploring the resources posted at <http://earth2class.org/site/?p=6916>.

Other themes in the E2C workshops offered during the current academic year have included: "Trees, Climate, and Societal Impacts," "How does the land affect Climate?" "How have glaciers behaved in Patagonia during the past 15,000 years?" and "Microbes in the Sea." The E2C homepage is <http://earth2class.org/site/>.

2015 Summit

(continued from page 17)

Participants provided feedback at many points during the sessions, and their thoughts are being processed by the conveners to formulate publications and reports that will inform next steps toward implementing the *NGSS* in states, districts, schools, and classrooms. The general conclusion was that this will not be easy but definitely must be accomplished for the Nation's future success.

A follow-up webinar was held on 9 June 2015. The archived version is available at <http://nagt.org/details/files/69358.html>. As you go through the presentation, also pay attention to the comments in the chat column on the right.

NJAAAPT

(continued from page 11)

The PowerPoint slides Goodman used in this presentation can be accessed online at <http://njctl.org/2015/03/ctl-announces-a-k-12-physics-strand-connecting-ngss-and-ccss-math-improving- both>. A survey of the slide presentations accessed by selecting "Courses," then "Science" from the <www.njctl.org> website suggests that Goodman may already have developed his K-12 thread. Courses are listed in science for K-8, then Algebra-Based Physics, all the AP Physics Courses, plus Chemistry and Biology and their respective AP courses. The presentations contain slides and teacher notes for presentations on a variety of topics appropriate for the grade level or course. They can be viewed as pdfs or as SMART Notebook applications.

High-Adventure Science

(continued from page 7)

also enable students to unpack the information without feeling they are being led to a pre-determined answer. This is unusual for school-based curricula, but in an age when news media and politicians make claims about science and the world, it is important to have a method for critically interpreting what is presented and learning about the science, even as new knowledge is added to the landscape. This is what studying at the frontier is all about.

Revisiting the STEM Workforce

Drawing from their *Science and Engineering Indicators 2014* (covered in the Winter/Spring 2014 issue of this *Newsletter*), the National Science Board (NSB) has issued a new report on *Revisiting the STEM Workforce*. The report is structured around three "primary insights," which are highlighted in the Executive Summary and then become the subjects of further discussion in the report's individual chapters.

Insight #1: *"The 'STEM workforce' is extensive and critical to innovation and competitiveness. It is also defined in various ways and is made up of many sub-workforces."* Some STEM workers' jobs are to increase knowledge in STEM fields. Other STEM workers' jobs are to apply that knowledge to accomplish a wide variety of tasks. There is no monolithic STEM workforce about which blanket statements can be made.

Because this report draws from the *Indicators*, which consider the science and engineering (S & E) workforce to consist of those with bachelor degrees in a science (including social sciences) or engineering field, its references to the S & E workforce apply only loosely to workers in STEM (science, technology, engineering, and mathematics) fields. The detailed discussion of this insight goes on to observe that although the S & E workforce was initially conceived of as producers of S & E research and development (R & D), the role of S & E in the workplace has broadened as technological advances have had their impact in a wide variety of jobs, not all of which require a bachelor's degree. In fact, the report notes that this sub-baccalaureate "technical STEM workforce" fills nearly 20% of all U.S. jobs and that its members earn twice as much and have half the unemployment rate as non-STEM comparably educated workers. In fact, this sub-baccalaureate "technical STEM workforce" is what Jonathan Rothwell calls "The Hidden STEM Economy" in his report of the same title for the Brookings Institution, reported in our Fall 2013 issue.

Because "there is no one-size-fits-all definition of the STEM workforce," the report goes on, "the findings of STEM workforce reports are sometimes not comparable to each other." (p. 8) One of the consequences of this is that there is no clear answer of whether there is a surplus or shortage of STEM workers in the U.S. Arguments that there is a shortage include higher wages and more time required to fill STEM jobs and that innovation produced by STEM workers increases the need for more STEM workers, though elsewhere the report acknowledges that innovation is realized not to result exclusively from S & E R & D. Arguments that there is a surplus of STEM workers include the failure of economic signs of a STEM worker shortage to materialize and the long time required to get an academic tenure track position after a Ph.D. The answer to the "surplus or shortage" question is also acknowledged to depend on the field and level of STEM employment.

Insight #2: *"STEM knowledge and skills enable multiple, dynamic pathways to STEM and non-STEM occupations alike."*

The table below showing the distribution of employment according to the field of highest degree shows a great deal of crossover between those trained in S & E fields and employment elsewhere and vice versa. Yet a majority of those trained in S & E fields feel that their job is related to their training, and the percentage of those trained in physical sciences working in an S & E field increases with the level of degree (38% of bachelor's, 58% of master's, 78% of doctor's). Career pathways, determined by interests and opportunities, are as varied as the number of workers, and the link between education and jobs is especially loose in computer science.

The report goes on to observe that because of the many career pathways that can be traveled after high school, "beyond primary and secondary schooling, the pipeline metaphor is less useful and even misleading." (p. 14) "To ensure a strong, flexible STEM-capable workforce in a 21st-Century economy, our Nation must ensure that all students acquire a strong foundation in primary and secondary school." (p. 14) By looking at workers in terms of their career pathways rather than their degrees, we move "away from a near-term focus on educating individuals for *today's* jobs to a strategy that focuses on

(continued on page 20)

field of highest degree	total	S&E occupation	S&E-related occupation	non-S&E occupation
S&E field	100	35.1%	13.7%	51.0%
S&E-related field	100	6.2%	72.7%	21.1%
non-S&E field	100	20.5%	29.3%	50.2%

Workforce

(continued from page 19)

equipping individuals with applicable skills and generalizable STEM and non-STEM competencies need to adapt and thrive amid evolving workforce needs." (p. 15)

Insight #3: *"Assessing, enabling, and strengthening workforce pathways is essential to the mutually reinforcing goals of individual and national prosperity and competitiveness."* Governments, educational institutions, and employers have a responsibility to insure that all benefit from high quality education and that pathways from education to employment are kept open.

"If essential STEM pathways are not attractive relative to other career options, too few students may undertake and persist in STEM courses of study." (p. 16) A primary indicator making STEM pathways attractive is their lower rate of unemployment, but this does not reflect the willingness of post-docs to linger in temporary positions. Other indicators are wages, which are higher for lawyers and doctors than for PhD's in basic sciences, and willingness of STEM-trained workers to work outside the field of their highest degree because of inability to find a suitable job in it. Yet other STEM-trained workers choose to work out-of-field because of other attractions of their jobs, and this is a reason to keep STEM pathways attractive.

STEM-trained workers are not confined by national boundaries, and *Indicators* data find China and other countries seeking to compete with the U.S. through R & D. This especially affects the U.S. because more than 40% of natural scientists and engineers with doctorates in the U.S. are foreign-born, compared with only 13% of the U.S. population being foreign-born. What is currently attracting foreign-born students who have come to the U.S. to study to remain here to work must continue to attract them.

In addressing the needs of business, a 2011 report from The Manufacturing Institute cited "difficulty finding workers with specific STEM skills . . . and 'employability' competencies. . . ." (p. 20) The NSB wonders whether this "skills mismatch" relates to specific STEM skills or general qualifications, to new or experienced workers, or to a specific geographical region. They expect that these skills mismatches can be addressed through on-the-job tailored programs and that more skill updating opportunities be offered to U.S. STEM workers.

Returning to the issue of the lengthy period for post-docs after they earn their Ph.D., the report notes that the basis for research in STEM fields is the population earning doctorates in STEM fields, but "since the 1970s, there has been a steady decrease in the share of full-time faculty among all U.S.-trained S & E doctoral holders employed in academia" and "a general decline in the proportion of S & E-trained PhDs in academia who have achieved tenure." (p. 20) The "average age of receipt of a first major NIH grant is 41." (p. 21) To cope with these trends, calls have been sounded "for strengthening the preparation of doctoral students in STEM for a broad range of career pathways." (p. 21)

Although, as of 2014, whites comprise a minority of American public school students and will be a minority of the American population by mid-century, the only two groups not underrepresented in the STEM workforce are white and Asian males. It is for this reason that all STEM career pathways must be kept open to all. This access to education must also eliminate the "achievement gaps" that have disadvantaged returning veterans.

The Introduction to the report states that "It is our hope that these insights will help government, education, and business leaders make better and more informed decisions and foster a more productive dialogue about how to maintain a strong STEM-capable workforce in the long term." The report can be accessed online at <http://www.nsf.gov/nsb/publications/2015/nsb201510.pdf>.

climate change divisiveness

(continued from page 4)

mate sensitivity. Given the difficulty of getting data on cloud properties and inputting it to models, Fasullo and Trenberth considered relative humidity (RH), correlated with cloud cover but easier to measure, and found that "only models with relatively high climate sensitivities (~4^{o}C for a doubling of CO_2) replicate the observed seasonal RH changes."

Some analysis of recent measurements might also be instructive. Relative to a pre-industrial atmospheric concentration of carbon dioxide of 280 ppm, atmospheric carbon dioxide concentration has already risen to 400 ppm. This is not a doubling, and risking such a doubling is something we would want to prevent, but the global temperature has already increased by 1^{o}C from 1910 to 2010 (it remained relatively constant between 1850 and 1910). Since this 1^{o}C temperature increase occurred while the increase in atmospheric carbon dioxide concentration was less than a doubling, we should expect that Earth's climate sensitivity is more than the 1^{o}C which Happer advocates.

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Renee Clary and James Wandersee, "Finding the CO_2 Culprit," *Sci. Teach.*, **82**(3), 23-29 (Mar 15).

This article describes an acivity in which students tabulate data available online for generation of carbon and carbon dioxide emission by human activity (from http://cdiac.ornl.gov/trends/emis/tre_glob.htm) and from volcanoes (from http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2324-9250/issues, then select T. Gerlach, "Volcanic versus anthropogenic carbon dioxide," *EOS*, **92**(4), 201-203(2011)), only to find that, climate change deniers' claims notwithstanding, the former clearly dwarfs the latter. Moreover, while the former continues to increase, the latter remains essentially constant.

2. Stacy McCormack, "Policy, Literacy, and Energy," *Sci. Teach.,* **82**(3), 30-34 (Mar 15).

Motivated by R. R. Muller's *Physics for Future Presidents*, this author grouped her students into researching different energy sources according to their own source of greatest interest. They were directed specifically to focus on answering four basic questions: 1) How does the energy source work? 2) What are the advantages of the energy source? 3) What are the disadvantages of the energy source? 4) Were there ever any major historical disasters or catastrophes related to the energy source? The students as a class were then asked to formulate an energy policy on the basis of the results of their research.

3. Ian L. Pegg, "Turning Nuclear Waste into Glass," *Phys. Today*, **68**(2), 33-39 (Feb 15).

The editor of this *Newsletter* toured the Hanford, WA, site which produced plutonium for nuclear weapons in World War II and now houses the nuclear waste from that effort. He learned that, in addition to contaminated buildings, that waste occupied 177 underground tanks. According to this article, in addition to the 210,000m^3 of waste stored in those tanks, an additional 470,000m^3 were "intentionally discharged into the ground." This waste still needs to be isolated from the environment. The author of this article, who directs the Vitreous State Laboratory at the Catholic University of America n Washington, DC, describes, after "false starts and cost and schedule overruns," how this is presently planned to be done, through vitrification (incorporating the waste into glass).

He points out the benefits of vitrification: "Glass is an amorphous material and is able to incorporate wide range of elements over wide composition ranges. Its amorphous nature also makes glass relatively insensitive to the effects of radiation and radioactive decay, which can include significant atomic displacements in the structure." He has a "one third scale pilot for the Hanford Tank Waste Treatment and Immobilization Plant's (WTP's) high-level waste vitrification system" in his lab. It uses Joule-heated ceramic melter technology, with which the U.S. has much experience since its development in the 1970s, but the unusual and diverse composition of the Hanford waste promises to pose unusual and diverse challenges to its vitrification. "The WTP contract was awarded in late 2000 based on a projected cost of $4.3 billion and startup in 2007. In 2006 the cost was revised to $12.3 billion and startup was delayed to 2019, and further delays appear likely. A 2012 Government Accountability Office report, which estimated the cost at $13.4 billion or more, identified the root cause of the cost increase as the decision to fast-track the project and start construction while design and testing was still in progress." Meanwhile, waste from 12 underground single-shell tanks has been transferred to double-shell tanks.

4. Joel Achenbach, "The Age of Disbelief," *Nat. Geog.*, **227**(3), 30-47 (Mar 15).

This article discusses the rise in skepticism about science, focused on five issues: climate change, evolution, the Moon landing, vaccinations, and genetically-modified food.

5. Cheryl Katz, "New Desalination Technologies Spur Growth in Recycling Water," *YALE Environment 360* (3 Jun 14).

New technologies – including forward osmosis, "semi-batch" reverse osmosis, "plant in a box," hybrid-thermal membranes, direct solar evaporation, flow-through electrode capacitive desalination, and perforated graphene membranes – are enabling water to be desalinated with less energy and cost. They are even more effective recycling water that as just been used. More than 17,000 desalination plants operate in 150 countries throughout the world. (*YALE Environment 360* is an on-line magazine from the Yale School of Forestry and Environmental Studies. Google it, then type the date of issue into the search box.)

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Mark Miodownik, *Stuff Matters: Exploring the marvelous materials that shape our man-made world* (Houghton Mifflin Harcourt, New York, 2013). ISBN 978-0-544-23604-2. $26.00.

The term may not yet be familiar, but at some level almost everyone functions as a materials scientist. Even pre-schoolers evaluate tastes, smells, and textures as they make choices. Through a lifetime we continue to expand and refine knowledge of the substances that affect our lives. While materials science draws on information from physics, biology, chemistry, mining, agriculture, metallurgy, and engineering, it focuses more on *application* than on pure research into the unknown. One need not share the author's enthusiasm for chocolate to enjoy reading about why so many of us do.

British scientist Miodownik employs his own experiences and preferences to entice the reader to sample the pleasures of his professional studies. His path into this science began oddly. As an adolescent he was mugged by a razor-blade wielder who slashed through layers of clothing and skin. Reflecting about the weapon itself inspired a curiosity about composition and effects of other objects. The incident somehow started his exploring of interactions between people and their surroundings.

He provides just enough data from various sciences to answer the "why" questions about materials to satisfy without becoming pedantic and tiring. However, the professional scientist will not feel patronized by the brief but lively presentation of the basics from his or her field. The researcher herein avoids laboratory settings and abstract discussions on states of matter in favor of boyish enthusiasm for specific encounters with the solid world. He touches on the geological and historical processes that over time provided the steel in the aforementioned blade, concrete for ancient Rome's Pantheon, natural and man-made diamond, paper's differing qualities, porcelain and newer ceramics, and other everyday products.

Readers are likely to share Miodownik's fascination with three families of products that will influence the 21st century: human body replacement parts from 3-D printed plastics, exotic varieties of aerogels, and newer carbon forms ranging from buckyballs to graphene. Carbon fiber already serves as the structural favorite for a range of products from golf clubs to exotic racing sailboats to Boeing's Dreamliner fuselage. Electrical and even magnetic properties of carbon under development point to its replacement of silicon in computer chips to achieve startling improvements in size and performance.

Generous reviews of the book convinced me to buy and read it. The jacket quotes Oliver Sacks: "I stayed up all night reading this book. Miodownik writes with such knowledge, such enthusiasm, such a palpable love for his subject." This reviewer admits to spreading the pleasure over parts of three days.

\- John D. White

Naomi Klein, *This changes everything: Capitalism vs. the climate* (Simon & Schuster, New York, 2014). 576 pp. $30. ISBN 978-1451697384.

In the book review section of *The New York Times* last fall Rob Nixon declared Naomi Klein's latest book (*This changes everything: Capitalism vs. the climate*) to be "almost unreviewable." I empathize. The body of the book is more than 450 pages long, dense, with hundreds of endnotes, and covers so many topics that no reviewer can do justice to them all.

The scope of *This changes everything* has not stopped reviewers from writing about it. The book has been called powerful, uncompromising, ambitious, and fierce. It is all those things, and Klein's book is also an important and timely call to action. In particular, the book's focus on "capitalism vs. the climate" raises questions not given sufficient attention in most discourse about climate change. This review focuses on the book's key strengths and weaknesses as I see them.

A 2006 economic review (the Stern Review, conducted for the British government) stated that climate change is the greatest and widest-ranging market failure ever seen. Capitalist economies have not included the true cost of climate change in the price of fossil fuels and treat carbon emissions as harmless.

Klein is angry at policymakers who have allowed this situation to continue for decades after the science of climate change became clear. She is angry at the fossil fuel companies that have resisted change, that continue to search for new reserves although they already have found more fossil fuels than can safely be used, and, in too many cases, that fund disinformation efforts to undermine confidence in scientific findings. Klein's anger gives the book a polemical quality: *e.g.*, she seems to

(continued on page 23)

REVIEWS

(continued from page 21)

view fossil fuel companies as *Bad*, and indigenous people as *Good*, because they protest mining and drilling.

Klein writes, "Policies that simply try to harness the power of the market — by minimally taxing or capping carbon and then getting out of the way — won't be enough. If we are to rise to a challenge that involves altering the very foundation of our economy, we will need every policy tool in the democratic arsenal." She notes that there is "*no* scenario in which we can avoid wartime levels of spending in the public sector — not if we are serious about preventing catastrophic levels of warming."

However, the proposed remedies can best be viewed as a brainstorming effort rather than a comprehensive set of policy proposals. For example, Klein suggests paying poorer nations to keep fossil fuels in the ground, and taxing profitable fossil fuel companies to raise funds to combat climate change. She favors more institutions divesting from fossil fuel companies. World trade agreements pose serious barriers to combating climate change, Klein believes, and need to be modified.

Although these may be excellent suggestions, I wished for a more comprehensive and better-developed list of policy proposals. During WWII the U.S. turned the nation's production lines from automobiles to jeeps, tanks, and airplanes; should we re-tool industry today to produce tens of thousands of wind turbines and solar arrays quickly, using government subsidies? Would a substantial carbon tax be a good idea in the U.S.? If so, how will low-income people be helped as they adapt to higher fuel prices? Is rationing in order (say for gasoline)? How will states like Alaska, Kentucky, and Wyoming, whose revenues for state services depend so heavily on fossil fuels, be made economically viable as we phase out fossil fuels? Klein reports that capitalism is inadequate for the current crisis, but she does not paint a sufficiently clear picture of what aspects of capitalism need to change, when, or how.

This changes everything does point out that many needed changes could reinforce one another. For example, growing income inequality could be addressed by creating more good jobs in the "climate sector," and funds to pay for addressing climate change could be raised partly by increasing taxes on the wealthy. The book is also useful in calling for a mass movement, along the lines of the women's suffrage and civil rights movements, to pressure policymakers into moving faster and more wisely. Some members of this movement need to engage in civil disobedience, Klein believes, as part of the growing efforts in many nations that she calls Blockadia.

The book is suspicious of calls to address climate change through geoengineering, such as by injecting millions of tons of chemicals like sulfur dioxide into the upper atmosphere to create tiny droplets that would reflect more sunlight and reduce global warming. Klein points out that geoengineering poses serious risks and can easily be used as an excuse for not doing more to reduce greenhouse gas emissions.

Unfortunately, Klein's book gives too little attention to the problematic role of democracy in combating climate change. By its nature democracy makes it difficult for government to take hard steps like raising taxes and devoting large sums of money to address goals that are perceived by many voters as distant or of uncertain value. Were that not true, the U.S. would have made more rapid progress. Democracies are also prey to manipulation, such as when fossil fuel companies and conservative think tanks sow doubt about the causes of climate change. The *combination* of capitalism and democracy has been identified by other writers, including Jørgen Randers, as a formidable and perhaps insurmountable barrier to moving quickly enough to prevent runaway climate change. Many people in the Western world became rich and comfortable based on economies using fossil fuels in huge quantities. Persuading citizens in democracies to make major social and economic changes is slow, difficult work.

It is true that Naomi Klein is on the side of the angels, and *This changes everything: Capitalism vs. the climate* is a passionate call to action. Yet we must wait for a different book (or state climate plans, or other sources) to provide concrete, achievable plans to address the climate crisis in the U.S., a capitalist democracy.

Although science teachers usually take the lead in teaching about climate change, *This changes everything* is a reminder that the issue is not simply scientific. Climate change is also a complex economics problem, an ethical dilemma, a subject of international diplomacy, and a topic that draws on the history of colonialism and industrialization. I blog about *psychology* and climate change because better understanding how people think about the issue of climate change is vitally important in changing public attitudes.

- Andy Zucker

(*Editor's Note*: Andy Zucker recently retired as a Senior Research Scientist from the Concord Consortium. His blog about psychology and climate change is at http://climatepsychology.wordpress.com. A version of this review first appeared on his blog in February 2015.)

Infusion Tips

The late Dick Brinckerhoff suggested the following criteria for ways to infuse societal topics into our science courses: items should be a) challenging, b) relevant, c) brief, and d) require a value judgment. Consider the following:

1. There are several examples of disbelief by some of the public in conclusions reached by science: the theory of evolution, anthropogenic climate change, and efficacy of vaccinations. That some people believe that vaccinations against disease can lead to autism has caused some parents not to have their children vaccinated against measles, mumps, and rubella, thus allowing cases of these diseases to continue to affect our society.

According to *The Times of Trenton* on 3 February 2015, "A parent needs only to submit a signed statement indicating 'immunization interferes with the free exercise of the pupil's religious rights.'. . . Parents do not need to produce a letter from a clergy member or cite religious doctrine." Legislation has been introduced to require "a letter from a clergy member, and a detailed explanation on how their religious beliefs conflict with vaccines," but the state legislature has been reluctant to take action on it. If you were a member of the New Jersey legislature, what action would you take?

2. Drones have long been used for military missions, but recently they have been touted for such civilian applications as package delivery. After they are released, they can deliver objects to whatever targeted destination they are programmed for with no further human involvement. And if their targeted destination is the same as their point of origin, they can take photographs *en route* and thus execute a surveillance mission. Because of this privacy concern as well as concern about cluttering air space, the Federal Aviation Authority has drawn up a set of proposed rules governing their use. What kind of provisions would you like to see these rules include?

SCI & SOC ED MEETINGS

15 October 2015, Building Energy, New York City. Contact Mary Beddle, 413-774-6051X22.

22-24 October 2015, NSTA Conference, Reno, NV, "Science and Literacy: Creating Connections!" Visit <www.nsta.org>.

12-14 November 2015, NSTA Conference, Philadelphia, PA, "Revolutionary Science" Visit <www.nsta.org>.

3-5 December 2015, NSTA Conference, Kansas City, MO, "Raising the Stakes in Science" Visit <www.nsta.org>.

Clearinghouse Update

From time to time we update our readers on situations which have been described in our *Newsletter*.

Still More on Driverless Cars

After our Fall 2008 issue reported on Alain Kornhauser's talk to the Princeton Chapter of Sigma Xi about Princeton's entry into the DARPA driverless car competition, an update in our Fall 2012 issue reported on a Piaggio electric van modified to make it driverless and California legislation to provide for driverless cars on that state's roads. The 12 February 2015 issue of *The Times* (Trenton, NJ) reports on four prototype self-drive cars unveiled in Great Britain, where they will be tested at four trial centers, built at a cost of $29 million. Although Britain is reported to intend to "amend and review domestic road regulations by 2017," officials are not expecting fully driverless cars on British roads until 2030. An article in the same paper's 26 February 2015 issue describes Google's efforts with self-driving cars, which rely on data about the driving environment loaded into the car's computer. This article points out that making the car dependent on data about its driving environment limits its usefulness, that giving the car the ability to scan its surroundings for this data and then be able to respond to it would make it much more appealing.

Still More on Producing Tc-99m

An update in our Fall 2014 issue described two new approaches to producing the technetium-99m used in nuclear imaging procedures, following Resource #5 in our Winter/Spring 2014 issue calling attention to the need for them. The online *World Nuclear News* now reports yet a third approach in its 23 February 2015 issue: using low-enriched uranium from General Atomics to produce molybdenum-99 (which decays to technetium-99m) at the University of Missouri Research Reactor Center, and extracting the molybdenum-99 with General Atomics' Selective Gaseous Extraction. The University of Missouri research reactor, the largest of its kind in the U.S., already is the nation's most prolific producer of radioisotopes for medical applications and biomedical research.

According to the 1 May 2015 issue of *World Nuclear News*, Coquí RadioPharmaceuticals Corp announced in April the completion of the schematic design of a medical isotope production facility that would produce "7000 six-day curies of Mo-99" in Alachua, FL, and thus become the first U.S. commercial supplier of Mo-99.

Indigo and Cochineal

(continued from page 28)

the 1560s. Indigo plants have a single semi-wood stem, dark green leaves that are a pointed oval in shape in most species, with clusters of red flowers that look like butterflies, and which eventually turn into peapods. The plants can grow from two to six feet in height. The dye is obtained from the leaves through a process of fermentation which will be described in detail shortly.

Indigo production in the New World increased throughout the seventeenth century. The French colony of Saint Domingue eventually became the major producer of indigo, and it was judged to be of the best quality. The English gained their first indigo-producing colony in this part of the world in 1655 when they captured Jamaica. However, by 1740 sugar had replaced indigo as the main Jamaican crop but, at the same time, it was the beginning of the indigo boom in South Carolina, thanks to Eliza Lucas who was born in December 1722 on the island of Antigua, in the British West Indies. In 1738 her father, Col. George Lucas moved his family from Antigua to South Carolina, where he had inherited three plantations, though he returned to Antigua in 1739. Col. Lucas sent his daughter indigo seeds in 1740. She experimented with growing indigo in the new climate and soil, depending on the knowledge and skills of slaves who had grown indigo in Africa and the New World. Her 1744 crop was used for seed which she shared with other plantation owners. She proved that colonial planters could make a profit in an extremely competitive worldwide market. With her success the volume of exported indigo dye increased from 5,000 pounds in 1745-6 to 130,000 pounds by 1748 – indigo became second in value only to rice as the South Carolina colony's cash crop and contributed greatly to the wealth of its planters and the pre-Revolutionary colonies. In November 1776, when Benjamin Franklin sailed to France to enlist support for the U.S. Revolutionary War, 35 barrels of indigo were on board his ship, the *Reprisal*, to fund the war effort.

Unlike many women of her time, Eliza was educated, independent, and accomplished. She rejected two wealthy suitors, which was unusual in that era, before marrying

Charles Pinckney in 1744 at the age of 20. Their son Thomas was appointed Minister to Spain, where he negotiated Pinckney's Treaty (1795) to guarantee U.S. navigation rights on the Mississippi River to New Orleans. Thomas was the Federalist Vice-Presidential candidate in 1796. His brother Charles was a signer of the U.S. Constitution, was the Federalist Vice-Presidential candidate in 1800, and was the Federalist candidate for President in 1804 and 1808. Eliza developed cancer and sought treatment in Benjamin Franklin's Philadelphia Hospital, where she died in 1793. So great was her renown and importance to Colonial exports that President George Washington served as a pallbearer at her funeral at St. Peter's Church.

The production of natural indigo dye begins by soaking plant leaves in water, where, as a result of fermentation, the glycoside indican, a colorless, water-soluble compound, readily hydrolyzes to release β-D-glucose and indoxyl. Exposure to air converts indoxyl to indigo. (See diagram below.) The fermentation is enzymatic, involving flavin-containing monooxygenase (FMO) that exists in the leaves. The process usually takes place in a series of pools where the effluent from one step in the process is gravity-fed to the next. The liquid containing the indigo, which is insoluble in water, is then concentrated by evaporation, and the solid indigo paste is then pressed to expel water, cut into cubes and dried. The German chemist Adolf von Baeyer began working on the synthesis of indigo in 1865. His first synthesis of indigo in 1878 was from isatin, an indole derivative, and a second synthesis in 1880 from 2-nitrobenzaldehyde. Neither synthesis was practical for large-scale production. Johannes Pfleger and Karl Heumann Karl eventually came up with industrial synthesis starting with aniline by 1890. In 1897, 19,000 tons of indigo were produced from plant sources. By 1914 natural indigo production had dropped to 1,000 tons as the industrial product displaced it.

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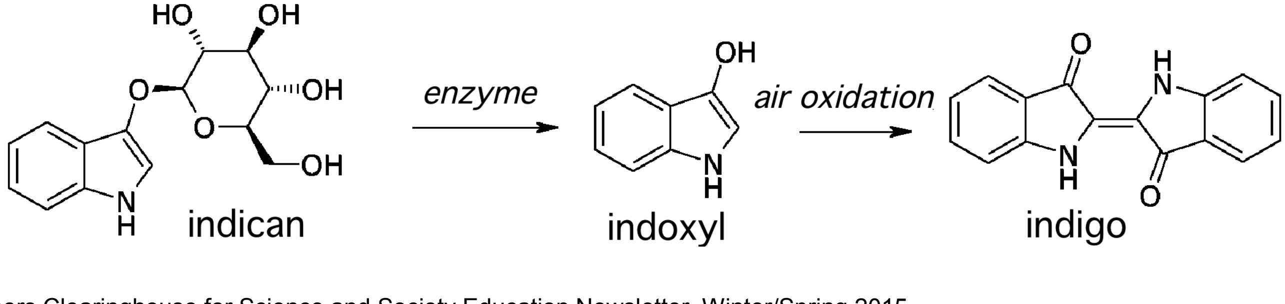


Indigo and Cochineal

(continued from page 25)

Because indigo dye is insoluble in water, dyeing requires that the blue solid be converted to leuco-indigo (white indigo) by reduction in acid solution. A preindustrial process for production of indigo white, used in Europe, was to dissolve the indigo in stale urine. Another preindustrial method, used in Japan, was to dissolve the indigo in a heated vat in which a culture of thermophilic anaerobic bacteria was maintained that generated hydrogen gas as a metabolic product and reducing agent. A more convenient reducing agent is zinc, though stannite ion may be used in lab processes. After the cloth (or thread) is immersed in the leuco-indigo solution it is exposed to oxygen and oxidized back to the blue form of the dye which also fixes the dye to the cloth.

When it first became widely available in Europe in the sixteenth century, European dyers and printers struggled with indigo because of its insolubility, requiring chemical manipulations, some involving toxic materials, resulting in injuries to workers. In the nineteenth century, English poet William Wordsworth referred to the plight of indigo dyers in his hometown of Cockermouth in his autobiographical poem "The Prelude," in which he wrote the following:

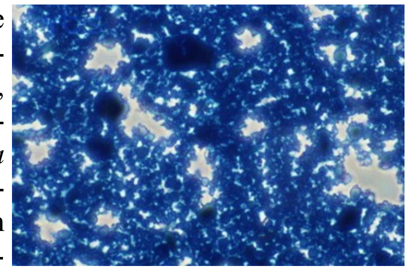
Doubtless, I should have then made common cause
With some who perished; haply perished too
A poor mistaken and bewildered offering
Unknown to those bare souls of miller blue

The major use of indigo dye is in "blue jeans," made by dying denim, a type of cloth first made in Nimes, France, around 300 C.E. Modern indigo denim is an interweave of two cotton yarns, one dyed indigo blue (the warp) and the other undyed (the weft). The term "indigo jeans" immediately brings to mind Levi Strauss.

Levi Strauss opened a West Coast branch of his family's New York dry goods business in San Francisco in 1853, which was the commercial hub of the California Gold Rush. Despite his later advertisements, Levi Strauss did not manufacture denim blue jeans until 1873, after he had formed a partnership with Jacob Davis, a Reno, Nevada, tailor who had been purchasing bolts of denim cloth wholesale from Levi Strauss & Co.

After repairing many pairs torn pants, Mr. Davis had the idea to use copper rivets to reinforce points of strain, such as on the pocket corners and at the base of the button fly. Davis did not have the required money to purchase a patent, so he wrote to Strauss suggesting that they go into business together. On 20 May 1873, the two men received U.S. Patent 139,121 for riveted blue jeans. (The rear pocket rivets were later removed because they scratched furniture. The fly rivet was removed because cowboys complained it conducted campfire heat.) The company created their first pair of the popular Levis 501 jeans much later, in the 1890s.

A new, environmentally friendly process using genetically modified *Echerechia Coli* bacteria is now used to make indigo. This bacterial source, and the synthetic route developed by von Baeyer, have replaced the processing of the *indigoferia tinctoria* plants for industrial uses, though craft uses remain. Indigo is also used as a food dye, as FD&C Blue No. 2, and, in Europe, as E132.



Cochineal

While indigo was a dye first extracted from a plant, cochineal dye comes from insects, specifically the female cochineal beetle, *Dactylopius coccus*. Cochineal beetles infect and feed on prickly pear cacti. They are then harvested and dried, and the red dye, carmine, is extracted into a hot, basic solution. Seventy thousand cochineal beetles are needed to produce just one pound of dried beetles.

The red color of cochineal was discovered and used by the Aztecs and Mayas, who valued it comparably to gold. Eleven cities conquered by Montezuma in the fifteenth century paid a yearly tribute of 2000 decorated cotton blankets and 40 bags of cochineal dye each. During the colonial period, the production of cochineal grew rapidly.

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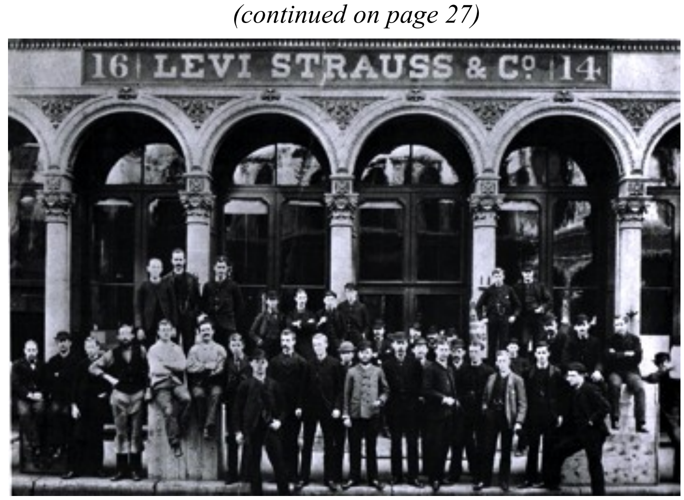

Indigo and Cochineal

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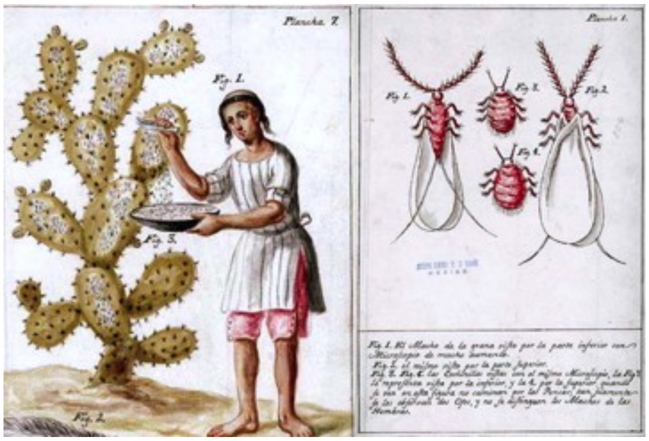
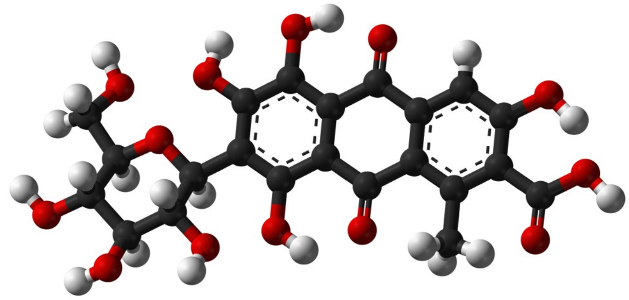


Produced almost exclusively in Oaxaca, Mexico, cochineal became Mexico's second-most valued export after silver.

After their conquest of the Aztec Empire, the Spanish, who recognized the superiority of cochineal to European madder-plant red dyes, imported it. It became the dyestuff of the redcoats of British officers and of Roman Cardinals. (Lower ranking officer uniforms were dyed with alizarin from woad, which has a brownish hue, or a mixture of alizarin and cochineal.)

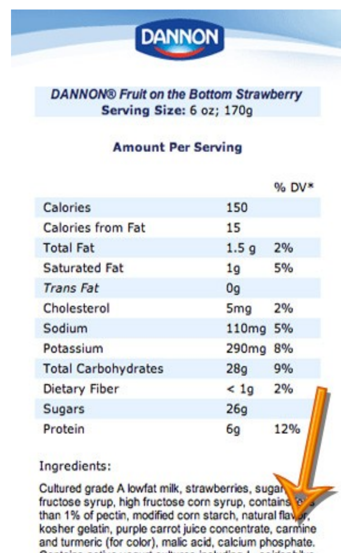
By the seventeenth century cochineal was traded as far away as India. The dyestuff was used throughout Europe and was so highly prized that its price was regularly quoted on the London and Amsterdam Commodity Exchanges. In 1777, a French botanist smuggled the insects and cactus pads to Saint Domingue, a French colony on the Caribbean island of Hispaniola from 1659 to 1804. This cochineal colony, as did another in Australia, failed to thrive, leaving the Mexican cochineal monopoly intact. (However the cacti transplanted to Australia did thrive, and ultimately had to be treated as an invasive pest.) The Mexican cochineal monopoly came to an end after the Mexican War of Independence (1810–1821). Large-scale production of cochineal emerged in Guatemala and the Canary Islands, which at its zenith, produced tons of the tiny beetle.

The dye molecule extracted from cochineal is the water-soluble carminic acid (pictured), which may be reacted with alum to form an insoluble carmine "lake." Carminic acid is also an acid-base indicator, changing from deep red to red-orange by adding sodium bicarbonate. The structure of carmine is chemically related to that of alizarin, the original redcoat dye extracted from the European madder plant.



The demand for cochineal fell sharply with the appearance on the market of alizarin red, first synthesized in 1867, which caused a significant financial shock in Spain as the cochineal industry disappeared quickly. The manual labor required for the breeding and processing of the cochineal beetle could not compete with the synthetic methods. Today, cultivation of the cochineal insect for dying fabric is done for tradition rather than for profit. Even synthetic alizarin has now been largely replaced by a colorfast red dye quinacridone which was developed by DuPont in 1958.

However, cochineal has become commercially valuable as a food and drink colorant, although most consumers are not aware that the terms "cochineal extract," "carmine," "crimson lake," or, in Europe, "E120" refer to a dye derived from an insect.



One reason for its popularity is that many commercial synthetic red dyes were found to be carcinogenic. However, when vegans learned several years ago that Starbucks was using cochineal extract as a colorant in its strawberry frappucino drinks they were "bugged," and claimed that there were insects in the drink, though it actually contained only the pure carmine dye compound. Starbucks quickly replaced carmine in this drink with lycopene, a red dye obtained from tomatoes. Carmine from cochineal is still used to color certain brands of strawberry yoghurt, other foods, candies and drinks, and also lipstick.

(*Editor's Note*: Dr. Drake based this article on a talk he presented to the Physics and Chemistry Teachers Clubs of New York on 23 January 2015.)

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Indigo and Cochineal: Uniform Colors

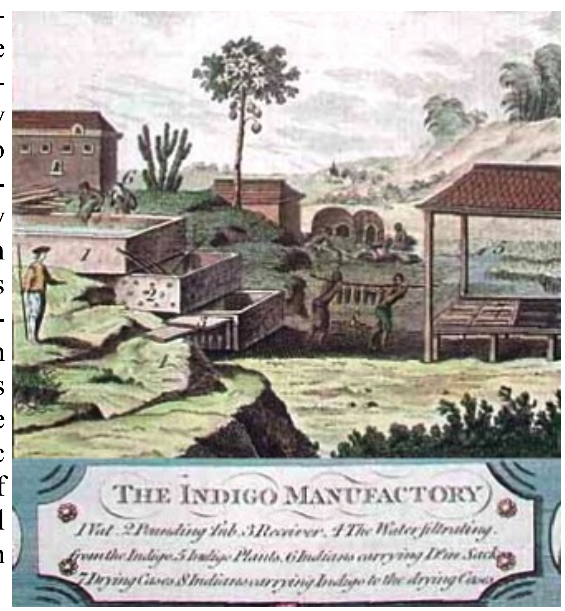
by Robert F. Drake

Humans have had a yen for decorating their homes for more than 30,000 years, based on the age of cave paintings of animals at Maros on the island of Sulawesi in Indonesia. European cave paintings using pigments and dyes at caves in Chavet in France, for example, are almost as old. The first dyeing of clothes dates from before 2600 BCE. An indigo dyed garment from about that period was discovered in the excavation of Thebes. The blue dye has had both political and religious connotations. The Hindu god Krishna is often depicted in blue and the Virgin Mary is shown draped in blue clothes in early Christian paintings. (The source of the ancient *tekhelet* of the Jews originally used to dye was lost and modern sources attribute the midnight blue color to the mollusk *Hexaplex trunculus*, but other possibilities include indigo and woad.)

Indigo

India is believed to be the oldest center of indigo dyeing in the Old World, and it was a primary supplier of indigo via Arab traders to Europe as early as the Greco-Roman era. The first mention of the dye was in about 450BCE by the Greek historian Herodotus who was born in Halicarnassus, now in modern-day Turkey. Evidence of the source of the dye may be seen in the Greek word for the dye, *indikon* ("Indian"). Romans used the word *indicum*, which passed first into Italian and eventually into English as the word *indigo*. Indigo was a rare commodity, particularly in Europe where the Celts used the native woad to dye their skin blue to frighten the conquering Julius Caesar. The dye became more widely known during the Crusades when it became one of the valued "spices" that Italian merchants acquired in Cyprus, Alexandria, and Baghdad, end-points for caravans from the Far East. But the trade in indigo dye became a commercial force only after 1498 with the discovery of the sea route to India by the Portuguese explorer Vasco da Gama, allowing the establishment of direct trade with India, China, and Japan.

The natural source of indigo dye is a leguminous plant of the *Indigofera* genus, of which hundreds of species have been identified. The commercial history of the dye centers around *indigofera tinctoria* (native to India and Asia) and *indigofera suffructiosa* (native to South and Central America and sometimes referred to as Guatemalan indigo). The Guatemalan variety of indigo was cultivated by Spanish overseers on plantations in Honduras and on the Pacific slopes of Central America in



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