TEACHERS CLEARINGHOUSE

FOR SCIENCE AND SOCIETY EDUCATION NEWSLETTER

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The Gap between what Science Education is and could be

One lead story in our Fall 2005 issue bemoaned that nothing had been done to address the issues raised by *A Nation at Risk* more than 20 years before. The other lead story in that issue held out hope that "Rising Above the Gathering Storm: Energizing and Employing America For a Brighter Economic Future" would change all that.

Ten years since then and still nothing has happened – except for the *Next Generation Science Standards* (NGSS), which envision a new way to teach science. "Ultimately, the task of realizing this vision rests with teachers," who will need to acquire new knowledge and understanding in order to implement the NGSS, states a new report on its first page. To determine how best to do this, the Board on Science Education in the Division of Behavioral and Social Sciences and Education of the National Academies, supported by the Merck Company Foundation, convened a 14-member committee. Their 256-page report, edited by Suzanne Wilson, Heidi Schweingruber, and Natalie Nielsen, is titled *Science Teachers Learning: Enhancing Opportunities, Creating Supportive Contexts*. It was published in 2015 by the National Academies Press, ISBN 978-0-309-38018-8, and can be downloaded online at <www.nap.edu/download.php?record_id=21836>.

After an introductory first chapter and a second chapter describing the NGSS, the next six chapters describe the committee's findings and conclusions about the gap between science education at present and what it could be. The third chapter is titled "The Current Status of Science Instruction" and explains that the "current status" was ascertained from the 2012 National Survey of Science and Mathematics Education (NSSME), the 2011 National Assessment of Educational Progress (which tested fourth and eighth grades only), the 2013 Teaching and Learning International Survey, and the 2011 Trends in International Mathematics and Science Study (which also surveyed only grades four and eight).

Science teaching in those years would not be expected to meet the NGSS, because they were not promulgated until 2013. But Iris Weiss and her colleagues at Horizon Research classified only 15% of the science lessons they studied as being comparable to a lesson based on the NGSS. They also classified 54% of the elementary school lessons, 78% of the middle school lessons, and 66% of the high school lessons as being ineffective. One particular deficiency in the science lessons they studied is lack of "systematic sense-making" – the lessons were found to be more focused on textbook explanations and well-organized presentations. This is phrased more formally the first conclusion:

Conclusion 1: *An evolving understanding of how best to teach science, including the NGSS, represents a significant transition in the way science is currently taught in most classrooms and will require most science teachers to alter the way they teach.*

"Creating new and productive ways to support science teachers depends on understanding not only current instructional practice but also the current science teaching workforce," opens Chapter 4, titled "The K-12 Science Teaching Workforce." To get a sense of the K-12 science teaching workforce, the study committee commissioned three analyses, one examining the National Center for Education Statistics 2007-2008 Schools and Staffing Survey and two data bases in Florida and New York. The number of female science teachers outranks the number of males – 70/30 in middle school, 54/46 in high school. Most of them are white and over 40 years old, with half teaching at least 10 years. In contrast with only 5% of elementary teachers who were science majors, most high school science teachers have a science major, but not necessarily one in the subject they presently teach.

In addition to the teachers' academic background, Chapter 4 also addresses their retention and professional development. Seventeen percent of new high school science teachers leave after their first year, with another 9% following after two years, and only 46% remain after eight years. (That half of them have more than 10 years of experience results from the fact that 30% of those leaving in the first five years return, most of them after birthing and rearing their children.) The attrition rate for elementary teachers is much less, with 8% leaving after

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AN EDITORIAL: Saying Goodbye to Some Friends

When John M. Fowler, founder of the then Triangle Coalition for Science and Technology Education, retired, I made sure that I was there to wish him all the best in person. The Clearinghouse's affiliation with the Triangle Coalition, which began in 1990, was my third interaction with Fowler in three phases of his life. The first had been teaching a laboratory section of his introductory physics course at Washington University when I was a junior physics major there in 1960-1961. Later, in the summers of 1978 and 1979, I worked with him on NSTA's Project for an Energy Education Curriculum. In the first summer I brought my knowledge of nuclear physics to bear on a curriculum to teach about nuclear energy, which I was later able to bring to the New York Energy Education Project. In the second summer I learned that the greenhouse effect I had learned about at the Summer Institute in Space Physics in 1962 could pose a threat to Earth's climate if carbon dioxide emissions from fossil fuel combustion got out of hand.

For a quarter century the Clearinghouse's affiliation with what became the Triangle Coalition for STEM Education connected us to the larger STEM Education community, and we were happy to receive permission to reprint their dispatches to share with our readers. Then, in February, came the letter that "the loss of the Einstein Fellows grant [because the Department of Energy decided to run the program themselves in-house] and the inability to procure additional grants" had "resulted in a financial condition that is no longer tenable." The Coalition's mission, "to bring together government, business, and education to enhance our members' efforts to foster a STEM literate workforce and citizenry," would live on in those members' efforts, but the Coalition would no longer exist.

Thus, the masthead of this issue no longer bears the inscription, "Affiliated with the Triangle Coalition for STEM Education." In effect, it leaves us out on our own, since the inscription, "Sponsored by the Association of Teachers in Independent Schools," had been removed at the end of 2013. This sponsorship had existed since the founding of the Clearinghouse in 1982, because the three cofounders had met at a meeting of the Association of Teachers in Independent Schools (ATIS) and convened our organizational meeting with science teachers from independent schools. All three of us later served on the ATIS board, and I was its president from 1989 until 1992. But when my inquiry on the eve of ATIS's centennial about how that centennial would be commemorated met with no response, I was saddened to learn from finding no presence of ATIS on the web that it, too, no longer existed.

Such, also, has also been the fate of another organization which played a major role in the evolution of the Clearinghouse, the National Association for Science, Technology, and Society (NASTS). It was founded at the third Technological Literacy Conference in the winter of 1988, and reporting on these conferences continued to be a dominant feature of this *Newsletter* for many years, since its sessions on STS education were filled with excitement about more relevant ways to teach science. By 2004, though, it seemed that the previous focus on education had given way to an emphasis on sociological critiques of science and technology; our final report from the Technological Literacy Conferences was from the twenty-second in 2007 and was limited to coverage of the memorial for Clearinghouse Cofounder Nancy Van Vranken. NASTS later rebranded itself as the *International* Association for Science, Technology, and Society, and its website continues to advertise its 2009 conference.

Having had to say good-bye to some close friends, the Clearinghouse continues and has been grateful to find some new friends, primarily the "Physics and Society" group in the American Association of Physics Teachers. As long as we are able, and to the best that we are able, we will continue to serve as your Clearinghouse for news on science and society education. We also welcome your participation in doing this.

\- John L. Roeder

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>.

Two Energy Education Summits

A Summit for Energy Educators

"Energy is one of the most important ideas in all of science," because it is used by all the sciences. Yet, because each of the sciences uses energy in a different context, students can fail to realize that all these contexts are referring to the same concept. Add to this the connotation of the word outside its scientific use and the fact that energy is an abstract scientific concept that is calculated rather than measured directly and you can see the reason that the University of Massachusetts Boston, Weizman Institute of Science, Michigan State University, Leibniz-Institute for Science and Mathematics Education, and Trinity University secured NSF funding to convene "40 scientists, science educators, and teachers . . . for an energy summit to better understand the importance of the energy concept in school science and how to best promote student understanding of the energy concept" (p. 2) at Michigan State in December 2012. There was another reason as well: the Next Generation Science Standards (NGSS) give teachers a "new challenge to teach energy as both a core disciplinary idea and a crosscutting concept." (p. 2) (See listing on pages 12-14 of this issue.)

The summit sought to address three questions:

1) "What should people know about the energy concept?"

2) "What are the challenges we are facing in teaching students about energy?"

3) "What can be done to meet the challenges?" (p. 5)

and set three goals:

1) "to synthesize current research on the conceptual understanding of energy."

2) "to identify directions for future research on the teaching and learning of energy."

3) "to foster international collaborations among science education researchers." (p. 7)

The quotations above are taken from the published book emanating from the summit: Robert Chen, Arthur Eisenkraft, David Fortus, Joseph Krajcik, Knut Neumann, Jeffrey Nordene, and Allison Schiff (eds.), *Teaching and Learning of Energy in K-12 Education* (Springer, Heidelberg, 2014), ix + 379 pp. ISBN 978-3-319-05016-4. This book is organized into parts devoted to the three questions it addressed plus one additional: "What does the research say about the learning about energy?" The researcher summit also paved the way for a teacher summit in July 2013, which some of the re-

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A Summit for Energy Teachers

The year following the Summit for Energy Educators at Michigan State University (separate story, this issue), a Summit for Energy Teachers was held at the University of Massachusetts, Boston. Like the proceedings of the Summit for Energy Educators, the proceedings of the Summit for Energy Teachers have been published – just released by the National Science Teachers Association this year, edited by Jeffrey Nordine (one of the editors of the proceedings of the Summit for Energy Educators) and titled *Teaching Energy Across the Sciences, K-12*.

Although the targeted audiences for the two summits were different, they also overlapped, and this overlap was designed so that energy educators attending the teachers' summit also participated in the educators' summit; and teachers who participated in the educators' summit also participated in the teachers' summit. According to the Foreword to *Teaching Energy Across the Sciences* by Helen Quinn (one of the educators who has participated in the educators' summit), the teachers' summit was purposed to facilitate teaching energy as a cross-cutting concept in the Next Generation Science Standards (NGSS). Other participants in the educator's summit who made presentations at the teachers' summit (in addition to Quinn and Nordine) were Arthur Eisenkraft, Joseph Krajcek, David Fortus, Robert Chen, Knut Neumann, Pamela Pelletier, and Allison Scheff.

In addition to editing *Teaching Energy Across the Sciences*, Nordine also wrote three of the book's ten chapters. In the fourth, titled "Talking About Energy," he begins by noting that "Energy," connoting "strength and vitality," derives from the Greek ενεργια and was coined by Thomas Young. Its scientific usage, like that of many words, is close to its general usage but not always precisely the same.

Nordine then goes on to what he calls "Five Big Ideas" in teaching about energy (developed in chapters 1 and 2), although his text lists only four:

1. <u>Energy forms</u>. Energy does not have a "form," because it can't be seen or measured directly, only calculated by a formula from quantities that *are* measured. Energy "forms" are "really just different ways of calculating energy."

2. <u>Energy Transformation and Transfer</u>. The former refers to changing forms, the latter to "crossing the boundary between systems or objects." (p. 65)

3. <u>Energy Dissipation and Loss</u>. Dissipation is the distribution of thermal energy throughout a sys-

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A Summit for Energy Educators

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searchers attended and all the teachers at the researcher summit attended.

Physicist Helen R. Quinn, who chaired the Committee on a Conceptual Framework for New K-12 Science Education Standards, provided a variety of insights to answering the questions raised by the summit in her contributed essay, "A Physicist's Musings on Teaching About Energy." Different units were used to measure different forms of energy "because they were discovered and categorized at different times," (p. 16) she noted. "Science did not arrive at the concept of energy by defining it, but rather by exploring it." (p. 16) Because this is also how students learn new concepts, it makes little sense to teach students the concept of energy by a definition. Rather, we need to enable students to connect "concepts related to energy used in different disciplinary contexts, as well as the everyday meanings of the word." (p. 16)

Quinn made the following comments about various forms of energy:

Thermal – must include elastic potential as well as kinetic for molecular vibrations.
Chemical – must be attributed to the combined system of fuel and oxygen, not just to the fuel alone. (A chemical bond is a *lack* of energy!)
Mass – not conserved in chemical reactions, accounts for thermal energy released.
Energy Flow – by movement of matter, by energy transport through matter without moving it, and by radiation (which has a negative connotation because of ionizing radiation) – usually all three processes are involved.

She also offered the following "Key Energy Concepts for K-12 Science Education":

1. "Only changes in energy matter. (Who cares how much you have if most of it is not negotiable?)"
2. "Any change in energy is balanced by some other change in energy. (You can't make or destroy energy, only move it around.)"
3. "Energy availability governs what can happen. (You can't do anything without energy.)"
4. "Energy tends to spread itself around as much as possible. (Entropy tends to increase.)"

She also offered the following caveats regarding the use of certain words with energy: "Producing" energy means producing fuel or generating electricity to "use." "Using" energy means transforming it to do what we want. And if the transformation is to thermal energy, she added, it becomes dispersed after its "use" to the point that it is considered to be "gone."

On introducing the energy concept to elementary students, Quinn observed that elementary students experience energy-related phenomena such as motion, sound, light, and temperature change, which are openings to introduce the scientific concept of energy. But, she asked, what is the most appropriate age to make this introduction?

Emeritus Professor of Physics Reinders Duit from the Leibniz-Institute for Science and Mathematics Education (Kiel, Germany) offered his thoughts on "Teaching and Learning the Physics Energy Concept." He considered learning the concept of energy in terms of four basic ideas: transformation, transfer, conservation, and degradation – in terms of Educational Reconstruction, which takes into account both the science content to be learned and the students' prior conceptions about it. He cited

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A Summit for Energy Teachers

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tem. When this reaches a point of non-recoverability, it is considered to be "lost."

4. *Energy Conservation and Use*. Environmentally, conservation means "keeping something in its original condition." (p. 67) Scientifically it implies neither creation nor destruction. "Use" of energy is really just its transformation or transfer.

Nordine then goes on to list energy terms that could be confusing:

1. *Work* – transfer of energy between systems by force.
2. *Potential Energy* – more properly "position" or "configuration" energy, because it derives from the position or configuration of objects in a system.
3. *Energy in Chemical Bonds* – when bonds are formed between particles in a system, then configuration energy decreases, so energy is required to break these bonds rather than be stored in them.
4. *Stored Energy* – usually considered to be potential energy but can also be kinetic, as in a flywheel; the key is accessibility.
5. *Heat* – a transfer process but not a synonym for thermal energy.
6. *Energy Flow* – suggests that energy is a fluid but also that it is conserved.

(*Editor's Note*: Nordine's four "Big Ideas" are seen to provide the framework for many of the presentations at the educators' summit (see separate story, this issue).)

at the U.S. Supreme Court

"What unique perspective does a minority student bring to a physics class?"

After U.S. Supreme Court Justice John Roberts asked "What unique perspective does a minority student bring to a physics class?" during the oral argument in *Fisher v. University of Texas*, in which the university's affirmative-action policy was claimed to promote less-qualified minority students over white ones, science writer Thomas Levenson was quick to respond in the context of the cultural milieu which Einstein described as necessary for his development of the special theory of relativity and enabled Kaća Bradoonjić to follow in Einstein's footsteps as a scholar of his general theory of relativity. His article, "What Chief Justice Roberts Misunderstands About Physics," in the 23 December 2015 issue of *The Atlantic*, cites Einstein's writing that the ten years he spent developing the special theory of relativity required such diverse reading as the philosophical works of David Hume and Ernst Mach and describes how Bradoonjić encountered Einstein's work while growing up in war-torn Sarajevo. "Roberts is thinking only about the answers, not the process of arriving at them," Levenson writes. "Physics, like any worthwhile inquiry, is not just a body of facts and methods. It is a way of being in the world that requires the full range of human experience." "Chief Justice Roberts's view of the physics classroom is too narrow to admit this diversity of human experience," Levenson concludes. "If such a view prevails, minority students will feel the blow first, but so will science, which is, after all, a search not just for knowledge, but for meaning."

The physics and physics education communities were quick to respond as well. Gary White, editor of *The Physics Teacher*, recalling his growing up in a position of white male privilege in Louisiana, noted in his February 2016 editorial that over 2000 physicists and astronomers had signed "An Open Letter to SCOTUS from Professional Physicists," which not only answered Justice Roberts's question but also took umbrage at the suggestion of the late Justice Antonin Scalia that "African Americans should perhaps go to 'less advanced' schools, schools where they won't feel like the 'classes are too fast for them.'" "Blaming affirmative action for our community's lack of progress in this regards is not only wrong, it is plainly ignorant," the Open Letter said. In his editorial, White issued "a call for papers on the topic of race and physics education."

The lead article in the February 2016 issue of *The Physics Teacher* was such an article: "Addressing Underrepresentation: Physics Teaching for All." Written by Moses Rifkin of University Prep in Seattle (WA), this article begins by noting the lack of women and underrepresented minorities taking physics and describes the measures he has taken in his classes to reverse this trend. First, he points out that teachers need to recognize their implicit biases and to realize that students are threatened by the expectations of stereotypes. Next, Rifkin notes that calling attention to the achievements of the great classical physicists gives students the impression that physics is the province of white Western males. To counter this, he gives examples of successful contemporary African Americans (of both genders) which he shares with his students. He also spends two weeks confronting the issue of demographic inequity in physics with his students. Not doing this would relegate physics to being "a collection of laws and problem solving tools"; moreover, it helps to meet the Next Generation Science Standard that "science is a human endeavor."

Paul J. Camp of Georgia Gwinnett College in Atlanta also weighed in with an open letter to Chief Justice Roberts in *Physics Today*, the flagship publication of the American Institute of Physics. Camp describes physics as "a European invention and an adopted child of Asian culture" and points out that "physics is a culture, with norms of behavior, practice, communication, legitimate argument, and rational critique" that "one learns to inhabit . . . developmentally. . . ." Historically, that culture has been what Rifkin describes in his *Physics Teacher* article, but Camp points out that it was outsiders like Albert Einstein who brought the new ways of thinking needed to develop the theories of relativity and quantum mechanics at the beginning of the twentieth century. Camp teaches his students about the culture of physics because he sees his role as "enabling the development of physicists and helping people to see 'physicist' as part of their identity." In a letter following Camp's, Philip Phillips of the University of Illinois at Champaign-Urbana makes many of the same points and specifically points out that "central to advancing physics is the ability to be an outsider."

IN THIS ISSUE

Koutavas presents Earth's climate history

Athanasios Koutavas, Physics and Engineering Professor at the College of Staten Island, presented the issue of climate change in the context of Earth's climate history to the Physics Club of New York at the United Federation of Teachers Headquarters Friday evening, 29 January 2016. He began by observing that New York City was covered by the Laurentide Ice Sheet 21,000 years ago. By 10,000 years ago, he continued, it had melted, and since then we have been living in an interglacial period.

Twenty-one thousand years ago, global sea level was 130 meters lower and the temperature was 5°C cooler. The Black Sea was sealed off from the Mediterranean, but the Mediterranean was not sealed off from the Atlantic Ocean. The oceans were also saltier, since their volume was 3% less than at present. Evidence of glaciers remains to this day in Central Park, and glacial moraines remain on Long Island and southern Connecticut, Rhode Island, and Massachusetts. There are two major ones, indicating two major glacial events, though there could have been more with their moraines erased by subsequent ones.

Koutavas continued by going back through the most recent million years, pointing out that they have been marked by ten 100,000-year cycles of rapid warming followed by slow cooling. But Northern Hemisphere glaciation is a relatively recent phenomenon, he was quick to add: it didn't begin until about three million years ago. Before that, Earth's temperature was warmer than it is today, and its atmospheric carbon dioxide concentration was greater then, too – about 425 ppm. He then showed on a chart that Earth's temperature at the demise of the dinosaurs 65 million years ago was 12°C warmer than at present and decreased ever since. Were it not for humans, we would expect a colder Earth today – the Little Ice Age (1500-1850) suggests that.

Koutavas detoured from his historic presentation to discuss how temperatures 65 million years ago are determined. The procedure is based on the evaporation of water from the ocean and its precipitation as snow on land. Because the isotope ^{18}O is heavier than the more abundant ^{16}O, it lags behind in the ocean, so more ice on land means more ^{18}O in the ocean. Relative to today's distribution of oxygen isotopes in the ocean, the ^{18}O-concentration in the ocean was greater by 0.1% and smaller in glaciers by 3.5% 21,000 years ago.

The 100,000-year cycles of the past million years match the periodicity of the eccentricity of Earth's orbit, which modulates two shorter cycles of three observed by Milankovitch: 41,000 years from Earth's tilt (ranging from 22.2° to 24.5°) and 23,000 years from precession of Earth's axis.

Koutavas observed that the current orbital geometry favors an Ice Age in the Northern Hemisphere (Earth at perihelion 3 January, aphelion 4 July), though this will reverse in 11,500 years. Although conditions in the Southern Hemisphere would be opposite those in the North, Koutavas noted that it is found that both hemispheres get hot and cold together, with Ice Ages occurring when the Northern Hemisphere has cool summers and warm winters. (With the two hemispheres connected by oceans, he said, it's hard to keep one warm and the other cold.) In addition to the $^{18}O/^{16}O$ ratio, Koutavas also stated that the historic atmospheric temperature can also be determined by the ratio of deuterium (^{2}H) to ordinary hydrogen (^{1}H).

Koutavas then showed on a graph that atmospheric carbon dioxide concentrations parallel Antarctic temperatures for the past 800,000 years, with temperature leading in some cases and following in others. Koutavas is looking to ocean circulation to explain when temperature change leads the atmospheric carbon dioxide concentration – after all, the ocean is the climate's greatest heat reservoir, mixes and overturns every thousand years. He added that the parallel between atmospheric carbon dioxide concentration and global temperature also results from the large amount of carbon dioxide dissolved in the oceans.

Koutavas concluded by observing that in the present interglacial period of the past 10,000 years, the temperature has been cooling from a maximum 6000-9000 years ago as a result of the Milankovitch cycles, most recently in the Little Ice age. Then there was warming since 1900, with a pause between 1940 and 1975. More recently, a global warming hiatus has been seen since 2002, except that 2015 has been reported as the hottest year on record, and it may be replaced by 2016. This hiatus is showing up in temperatures measured both by ground thermometers and satellites, although a recalibration of the ground thermometer temperatures by the National Oceanographic and Atmospheric Administration (NOAA) recently claimed that the supposed hiatus is not real. Reasons for discrepancies between actual temperatures and those predicted by models include measurement error, unknown cooling factors (regarded as unlikely by Koutavas), internal climate variability (*e.g.,* El Niño, which raises temperature, the Pacific Decadal Oscillation, Atlantic Multidecadal Oscillation), and model errors.

(*Added Note*: For a visualization of the events discussed by Professor Koutavas, Google "hhmi interactives," and select "Earth Viewer." This allows visualization of Earth at various ranges of times in the past, including the 21,000 year period discussed by Koutavas at the beginning of his talk. In addition to seeing the degree of glaciation at various times, graphs, including those for temperature and atmospheric carbon dioxide vs. time, can be plotted.)

Banta: A more efficient way to produce biofuels

Plants can use solar energy to extract carbon dioxide from the air to make reduced carbon fuels (fuels containing chemically-reduced carbon). But they don't do it efficiently. If the plant is corn, only 0.18% of the solar energy incident onto the corn field can be converted to ethanol. If the plant is sugar cane, the percentage of incident solar energy converted to ethanol is still only 0.20%.

Professor Scott Banta of Columbia University's Department of Chemical Engineering is looking for a better way to use renewable energy and atmospheric carbon dioxide to create biofuels. Such a way would allow us to use renewable energy to fly planes and to do without infringing upon agriculture. Most of his funding comes from the ARPA-E program of the US Department of Energy, which targets unusual approaches to what could be long-term energy solutions.

This was the basis for Banta's talk to the Physics Club of New York at New York University on 26 February 2016 on "Making Biofuels from the Wind or Rocks." His subtitle, "Engineering *Acidithiobacillus ferrooxidans* cells for biochemical production using electricity and CO_2," suggests his approach. *A. ferrooxidans* are iron-oxidizing bacteria, found in biomining operations, that fix carbon dioxide through the Calvin Benson Bussham cycle by oxidizing ferrous (Fe^{2+}) to ferric (Fe^{3+}) iron. By comparisons with the conversion of sugar (a 6-carbon molecule) to ethanol (a 2-carbon molecule), which Banta regarded as a "downhill" process, he noted that converting ferrous iron, carbon dioxide, and oxygen to ferric iron, water, and a biofuel as an "uphill" process. (He related the energy density of a fuel to the number of carbon atoms in its molecules.)

Banta's research consists of finding ways of enhancing this "uphill process" to make more biofuel product. One way is to use iron chelators, which increase the amount of biofuel product at higher pH. The use of metals other than iron is being considered, as well as genetically modifying the *A. ferrooxidans*. One such genetic modification has been engineered to make isobutyric acid (which is chemically and biologically easier to produce than the originally intended isobutanol); another has been engineered to make heptadecane. Although an automobile's internal combustion engine can run on pure isobutanol, Banta pointed out, advanced fuels, especially aviation fuels, are mixtures of several molecules to meet specific chemical requirements, and the details for achieving this have not yet been worked out.

Apropos of his title, "Making biofuels from the Wind or Rocks," Banta cited wind as an example of a renewable energy source. He noted that copper mines produce a lot of rocks with reduced chemicals – chiefly sulfur and iron – which can be used to make fuels. Already he is able to match sugar cane in the percentage of incident solar energy in the fuel he makes with carbon dioxide, iron, and *A. ferrooxidans*.

McManus offers a look at Earth's past climate

At an Evening for Educators on 18 March 2016 at the American Museum of Natural History in New York City, Dr. Jerry McManus of Columbia University's Lamont-Doherty Earth Observatory offered teachers a look in Earth's rearview mirror to ascertain past climates in a talk on "Sun and Earth: Cycles and Abrupt Shifts in Past Climate."

McManus opened by reminding us that Earth's climate has been both colder and warmer in the past than it is today. He added that Ice Ages have come and gone and that we are now living in a warm period between them. He distinguished climate from weather, noting that climate is the average of the weather over a long period of time, and pointed out that Earth's climate is a consequence of solar radiation onto Earth, how much of it Earth reflects, and the greenhouse gases in our atmosphere.

McManus also pointed out that solar radiation, the first determining factor of climate, is modified by gravitational forces to produce the Milankovitch Cycles. These gravitational forces change the eccentricity of Earth's orbit (in a cycle of 100,000 years), vary the tilt of Earth's axis (between 21.5^{o} and 24.5^{o}, in a cycle of 41,000 years) and cause Earth's axis to precess (in cycles between 19,000 and 24,000 years).

The amount of incident radiation reflected by Earth depends on conditions on Earth's surface: more, McManus said, is reflected by a dusty, dry, icy Earth. The third factor, greenhouse gases, absorb and re-emit infrared radiation given off by Earth.

Obtaining information about Earth's past climate comes from using "climate proxies." There are many of these, McManus said – tree rings, ice cores, corals, pollen, formanifera, and ice-rafted debris. But McManus's favorite is cores of deep sea sediments obtained from drilling ships, which drill cores hundreds of meters deep. He cited an example of deep sea sediment cores from two neighboring drill sites near the British Isles, for which the formanifera abundance indicated that the same time frame corresponded to two different depths.

Because water containing the lightest and most abundant stable oxygen isotope, ^{16}O, is more likely to evaporate than water made with the heavier ^{18}O, a larger $^{18}O/^{16}O$ ratio in a segment of an ice core indicates that the Earth was colder at the time. McManus displayed a slide

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Surfers and Scientists Partner for Research

by Michael J Passow, Earth Sciences Correspondent

The World Surf League (WSL), once known as the Association of Surfing Professionals, has promoted many of the major surfing championship events around the world for four decades. From their headquarters in Santa Monica, the WSL works with most of the best surfers across the globe in locations such as Australasia, Hawaii, Africa, South America, Japan, and Europe. So what does the WSL have to do with Science Research? Now, it turns out, A LOT!

On 5 Apr 2016, representatives of the WSL joined Columbia University (CU) administrators and scientists to announce the creation of the WSL PURE (Progressive Understanding and Respect for the Environment). This unique partnership with the Lamont-Doherty Earth Observatory (LDEO) will support pioneering research in ocean health and ecosystems, ocean acidification, sea level rise, and the role that the ocean plays in climate change. Simultaneously, the Columbia University School of Professional Studies is receiving support from WSL PURE to create new curricula for programs in ocean studies.

Paul Speaker, CEO of the World Surf League, announced that these partnerships "are the first steps in what we hope will become a global movement among our community and beyond, to protect the waters that are both our home and our playing field. By creating a generation of 'surfer scientists,' we aspire to create a voice for the oceans and to inspire and empower our global fan base and partners to become better informed about the issues plaguing the oceans, while providing educational opportunities so we can become an important part of real-world solutions."

Peter De Menocal directs the Columbia Center for Climate and Life and conducts oceanographic research at LDEO. He explained, "WSL PURE allows us to accelerate the urgent science we need to understand how these changes will impact things people care about most—access to food, water, shelter, and energy." He mentioned damage to the Great Barrier Reef caused by warming waters. "We're basically playing catch-up to understand what these changes mean for us and the planet."

Funding from the $1.5 million award will, in part, go to support research by marine biologists and others at LDEO who could not obtain sufficient support through the conventional research funding models. It will also foster development of new courses offered through the CU School of Professional Studies. Dean Jason Wingard said, "Investing in programming in the field of ocean science will prepare future generations of scientists, citizens, and expert practitioners who will have a broad and positive impact on our environment's future."

What's in it for the surfers? Jessi Miley-Dyer, Women's Commissioner of the World Surf League, pointed out that, "Surfing is unique in that its playing field is a living ecosystem. As surfers, it is incumbent upon us to do what we can to protect the oceans. Partnering with Lamont-Doherty and Columbia University is a great way to support thorough research into ocean health, and I'm excited to see where it leads."

Learn more at <http://www.ldeo.columbia.edu/news-events/world-surf-league-teams-columbia-support-ocean-science>.

American workers last in "problem solving in technology-rich environments"

American workers placed last among 18 industrial countries in "problem solving in technology-rich environments," according to a 2014 follow-up to a 2012 survey conducted by the Organization for Economic Cooperation and Development (OECD), designed to compare skills of younger and older adults and the unemployed. About four fifths of unemployed Americans could not spot an error when two columns of data were transferred to a bar graph. Even workers with college degrees did not perform as well as their international counterparts.

These findings are considered to reflect poorly on the U.S. education system and raise concerns about the future of the U.S. economy, which depends on technological innovativeness. They also convey the message that being literate about using technology doesn't automatically insure being able to use it to solve problems.

(*Editor's Note*: This article is based on an article by Douglas Belkin in the 10 March 2016 issue of the *Wall Street Journal*. "Problem-solving in technology-rich environments" is a domain surveyed in the Program for the International Assessment of Adult Competencies, described online at <nces.ed.gov/surveys/piaac/problem-solving.asp>. A sample problem from the original OECD survey can be found online at <www.oecd.org/site/piaac/Problem%20Solving%20in%20TRE%20Sample%20Items/pdf>.)

Free electronic copies of issues of this *Newsletter* back to 2009 are available. Just e-mail your request to the Editor at JLRoeder@aol.com

Pew samples Public and Scientists on Science and Society Issues

In our last issue we reported the results of a Pew Research sampling of the American public for their science literacy. Here we present the results of Pew's sampling of 3748 scientists (chosen randomly from the membership of the American Association for the Advancement of Science) and 2002 members of the American public (surveyed by phone interviews using standard techniques for a national poll) on science and society issues. The results, summarized in the table below, are part of a larger report, *Public and Scientists' Views on Science and Society*, by Cary Funk and Lee Rainie, first published by Pew Research Center on 29 January 2015. The URL for the roadmap to this report, which contains a link to a pdf of the report itself, is <pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society>.

Science and society issue	% U.S. adults	% AAAS members
Safe to eat genetically modified foods	37	88
Favor use of animals in research	47	89
Safe to eat foods grown with pesticides	28	68
Earth is getting warmer mostly because of human activity	50	87
Humans and other living things have evolved over time	65	98
Growing world population will be a major problem	59	82
Favor building more nuclear power plants to generate electricity	45	65
Favor more offshore oil and gas drilling in U.S.	*52*	*32*
Childhood vaccines, such as MMR, should be required	68	86
Astronauts are essential for the future of the U.S. space program	*59*	*47*
Favor increased use of bioengineered fuel to create a gasoline replacement	68	78
Favor increased use of fracking	*39*	*31*
The Space Station has been a good investment for the U.S.	64	68

Note that all issues are phrased in a "positive" format and that, with only three exceptions (which are italicized), the percentage of AAAS members exceeds that of the U.S. adult population, sometimes by a significant amount.

McManus offers a look at Earth's past climate

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showing that over the past 800,000 years minima in ^{18}O corresponded to the warmest part of Milankovitch cycles – and also maximum values of atmospheric carbon dioxide.

McManus distinguished the behavior of ice over Greenland and Antarctica, noting that it accumulates more rapidly over Greenland because of the greater snowfall there. The ice covering Greenland also melts more rapidly, and McManus concluded his talk by pointing out a serious consequence of this. He cited the Gulf Stream, which transports heat northward in the Atlantic Ocean and releases it to the atmosphere. This effect would weaken if there was an injection of fresh water into the North Atlantic Ocean, and such an injection is what melting Greenland ice is providing.

(*Editor's Note*: Earth Sciences Correspondent Mike Passow recommends a video of a similar talk several years back at <http://www.ldeo.columbia.edu/video/currents-conveyors-and-climate-change>.)

When Nature Strikes: Science of Natural Hazards

by Michael J. Passow, Earth Sciences Correspondent

Natural Hazards come in many forms and occur around the world. But some, such as tornadoes, are particularly common in the U.S. So it is important that our students learn what these potential threats are, how to prepare and respond to them, and the research being undertaken to learn more. These were motivations for "When Nature Strikes: Science of Natural Hazards," a series of short videos produced by NBC Learn in partnership with the National Science Foundation and The Weather Channel.

Topics include earthquakes, volcanoes, hurricanes, flash floods, landslides, tsunamis, space weather, tornadoes, and wild fires. Dr. Marshall Shepherd of the University of Georgia and the Weather Channel hosts each of the short (5 – 6 minutes) programs that provide brief explanations of the impacts each disaster can produce and interviews with scientists conducting cutting-edge investigations. You can view these either through the NBC Learn website at <http://www.nbclearn.com/whennaturestrikes> or the NSF website at <http://www.nsf.gov/news/special_reports/naturestrikes/index.jsp>. There is also an overview video entitled "When Nature Strikes—On the Front Lines."

To enhance opportunities for students and teachers to learn and do more, the NSF awarded the National Earth Science Teachers Association (NESTA) a grant to develop educational modules focusing on each of the nine topics. These were developed by NESTA using a strategy created for an earlier partnership with NBC Learn and available on the Windows to the Universe website, "Our Changing Planet" (https://www.windows2universe.org/earth/changing_planet/changing_planet.html).

The "When Nature Strikes" resources are available at <https://www.windows2universe.org/earth/natural_hazards/when_nature_strikes.html>. Each module includes a Summary, Student Learning Outcomes, Directions, Background Information, Extensions, online resources, and additional links. Developers were selected from experienced classroom teachers who are NESTA members. Every module was peer-reviewed by other classroom teachers and the NSF.

Three focus on dangers from the Solid Earth — earthquakes, volcanoes, and landslides. Three are weather-based: hurricanes, tornadoes, and flash floods. Two deal with the threats from wild fires and tsunamis, and the last explores the often-overlooked impacts of space weather, powerful emissions from the Sun that could be devastating to our power systems and other technologies. The types of learning activities vary widely, as might be expected when experienced teachers are challenged to create materials that will capture the attention of the hypothetical students who might use these.

There are, of course, many other online resources designed to enhance awareness of Natural Hazards. One example is the U.S. Geological Survey's "Science Explorer — Natural Hazards" (https://www.usgs.gov/science/science-explorer/Natural+Hazards). These include many more potential problems and disasters than are found in "When Nature Strikes." Units within the USGS also provide valuable resources, such as the Cascades Volcano Observatory (http://volcanoes.usgs.gov/observatories/cvo/teaching_resources.html).

Another federal agency that provides a suite of resources is, of course, FEMA (http://www.fema.gov/). Here, for example is a link to their "Children and Disaster" materials (http://www.fema.gov/children-and-disasters).

The NOAA National Weather Service "Vision" is "A Weather-Ready Nation: Society Is Prepared for and Responds to Weather-Dependent Events." To that end, you can find an array of resources at <http://www.weather.gov/safety>. These 18 modules range, alphabetically, from Air Quality to Winter Weather.

The important goal is to find or design useful learning activities for your students or other audience. "When Nature Strikes" and related resources can be of high value in meeting this goal.

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:

The belief that the MMR (measles, mumps, rubella) vaccine causes autism has figured more than once in this column (in our Winter/Spring issues of both 2009 and 2015). Now the most notorious practitioner of this belief, Andrew Wakefield, whose medical license was revoked by Britain's General Medical Council, has co-written and directed a documentary film, *Vaxxed: From Cover-Up to Catastrophe*. The film had been slated for inclusion in the Tribeca Film Festival but was pulled by Festival Director Robert DeNiro, who has an autistic son and had been sympathetic to showing it to spark conversation, because of objection that including it would endorse a point of view at variance with the findings of scientific research. This in turn brought objections that excluding the film constituted censorship. If you were the director of the Tribeca Film Festival, what would you have done?

(*Sources*: *Trenton Times,* 28 and 29 March 2016.)

Von Hippel reviews Iranian nuclear capabilities

Cofounder of Princeton University's Program on Science and Global Security Frank von Hippel spoke at the Princeton Plasma Physics Laboratory's "Science on Saturday" on "Dealing with Iran's Nuclear Program" on 30 January 2016. "Iran is in a tough neighborhood," he opened, noting that it was surrounded by two countries the U.S. has invaded (Iraq and Afghanistan) and two with nuclear weapons (Pakistan and Israel).

Regarding Iran's attempt to develop nuclear weapons, von Hippel continued by noting the two ways to do this: 1) the separation of fissionable ^{235}U (which comprises only 0.7% of natural uranium) from the more abundant ^{238}U. 2) bombardment of ^{238}U with neutrons to produce ^{239}U, which after two beta decays yield fissionable ^{239}Pu. Because one ^{235}U fission induced by the incidence of a slow neutron yields an energy of 200 million electron-volts (MeV) and the neutrons resulting from that fission double the fission rate every hundred millionth of a second, a kilogram of ^{235}U fissioned in this way releases the energy equivalent of 16 kilotonnes of TNT, the approximate yield of the nuclear weapon dropped on Hiroshima. The neutrons from a 1 MWt reactor can fission enough ^{238}U to produce a gram of ^{239}Pu in a day, 8 kg in 200 days (enough for a bomb). The Iranians had been pursuing both options.

Separation of ^{235}U from the more prevalent of ^{238}U was revealed by an exile group in 2002 to be conducted at the Natanz Uranium Enrichment Plant, which employed cascades of 164 centrifuges, some hidden below ground, to achieve a mixture that is 90% ^{235}U. Centifuges separate the two principal uranium isotopes because gaseous $^{238}UF_6$ will be harder pressed against the centrifuge walls, leaving uranium hexafluoride enriched in ^{235}U in the middle. Seven thousand centrifuges could produce a quarter kilogram of 90% ^{235}U per year.

The Iranians were found to be making ^{239}Pu at a reactor built at the site of the Arak heavy water plant – the heavy water was used to cool the reactor because it doesn't absorb as many neutrons as regular water. This reactor looked like one that India had built to produce plutonium for its nuclear weapons, but no plutonium separation facility was observed to be built.

Von Hippel next reviewed the sequence of events leading to Iran's nuclear weapons program:

2002: President G. W. Bush declared Iran-Iraq-North Korea to form an "axis of evil."

2003: Iran complied with the IAEA (International Atomic Energy Agency) demand to stop uranium enrichment and plutonium separation.

2003-2005: Britain, France, and Germany negotiated with Iran.

2005-2013: Iranian President Ahmadinejad restarted the nuclear program. Three times Benjamin Netanyahu threatened to bomb Iranian plants. Election of American President Obama and Iranian President Rouhani led to a cooling off period, after 10,000 centrifuges had become operational.

2009: The Fordow underground enrichment plant, designed for 2700 centrifuges, already had 700 producing uranium enriched to 20% ^{235}U from uranium enriched to 3.5% of ^{235}U. The justification given for uranium so enriched was production of fuel for nuclear submarines.

When it came to negotiating the present hiatus in Iran's nuclear weapons program, Iran refused to give up its Arak reactor and uranium enrichment programs. President Obama wanted Iran to stay at least a year away from making a nuclear bomb. The final settlement reduced the number of centrifuges and reduce the power of the Arak reactor from 40 MW to 20 MW and capped the of ^{235}U percentage to remain constant, with the ^{239}Pu to shipped to Russia for storage. This limits Iran's nuclear program for only 10-15 years, a point which von Hippel said points up the need to strengthen nuclear nonproliferation, which is of concern regarding Brazil and Argentina as well as Iran.

Von Hippel concluded his presentation by citing other nuclear weapons developments on the table. One is the 2003 El Baradei proposal which called for multinational control of enrichment. (Here von Hippel noted that the U.S. has no national commercial enrichment plant and that the only enrichment plant currently operating in the U.S. is the European-owned Urenco plant in New Mexico.) Von Hippel's other observation was that hopes for breeder reactors (which "breed" more fissionable ^{239}Pu than the ^{235}U they fission) have gone unfulfilled, with the U.S. eschewing the costly separation of plutonium that breeder reactors would produce. Fortunately, he said, Iran agrees with this policy. Von Hippel concluded by acknowledging the assistance rendered by Sayeed Hossain Mousavian, now at Princeton, in "explaining" Iran to Washington.

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

27-29 July 2016. Fifth Annual NSTA STEM Forum & Expo, Denver, CO. For information and registration, visit <www.nsta.org/stemforum>.

14-16 September 2016. World Nuclear Association Symposium 2016, Paark Plaza Westminster Bridge, London, UK. Visit <www.wna-symposium.org> or contact Sharon Gallagher on +44(0)20 7451 1521.

Energy in the Next Generation Science Standards

As noted in the story on the Energy Summit for Educators (page 3, this issue), "energy" shows up as both a core disciplinary idea and a crosscutting concept in the Next Generation Science Standards. The following lists the disciplinary core ideas and their performance expectations in which energy plays a role (those marked with an asterisk also involve energy as a crosscutting concept).

Discipli-nary Core Idea	Perfor-mance Ex-pectation	
K-PS3	K-PS3-1	Make observations to determine the effect of sunlight on Earth's surface.
	K-PS3-2	Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.
K-LS1	K-LS1-1	Use observations to describe patterns of what plants and animals (including humans) need to survive.
2-PS1	2-PS1-4	Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.
2-LS2	2-LS2-1	Plan and conduct an investigation to determine if plants need sunlight and water to grow.
*4-PS3	4-PS3-1	Use evidence to construct an explanation relating the speed of an object to the energy of that object.
	4-PS3-2	Make observations to provide evidence that energy can be transferred from place to place by sound, heat, light, and electric currents.
	4-PS3-3	Ask questions and predict outcomes about the changes in energy that occur when objects collide.
	4-PS3-4	Apply scientific ideas to design, test, and refine a device that converts energy from one form to another..
*5-PS3	5-PS3-1	Use models to describe that energy in animals' food (used for body repair, growth, and motion to maintain body warmth) was once energy from the sun.
*5-LS1	5-LS1-1	Support an argument that plants get the materials they need for growth chiefly from air and water.
*MS-PS1	MS-PS1-4	Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
	MS-PS1-6	Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.
*MS-PS3	MS-PS3-1	Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
	MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

	MS-PS3-3	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
	MS-PS3-4	Plan an investigation to determine the relationships among the energy transferred, the type of matter, the type of mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
	MS-PS3-5	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
MS-PS4	MS-PS4-1	Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
*MS-LS1	MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
	MS-LS1-7	Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
*MS-LS2	MS-LS2-3	Develop a model to describe the cycling of matter and flow of energy among living and non-living parts of an ecosystem.
*MS-ESS2	MS-ESS2-4	Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
MS-ESS3	MS-ESS3-1	Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
*HS-PS1	HS-PS1-1	Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
	HS-PS1-4	Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.
	HS-PS1-8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the process of fission, fusion, and radioactive decay.
*HS-PS3	HS-PS3-1	Create a computational model to calculate the change in the energy of one component of a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
	HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects).
	HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

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A Summit for Energy Educators

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several ways educators have conceptualized energy: 1) a conserved abstract quantity; 2) ability to do work (limited to mechanical energy); 3) ability to cause change (dependent on amount and type of energy); 4) ability to produce heat (limited to thermal energy); 5) kind of fuel; 6) a substance which flows (facilitates understanding transfer and conservation but poses difficulties for mechanics). He also cited several ways students are found to conceptualize energy: as something 1) centered on humans; 2) deposited; 3) used or produced; 4) active; 5) functional; and 6) fluidic.

Duit said that students are found not to use scientific language specific to energy in expressing themselves on energy-related issues. According to Duit, research shows that the learning progression of ideas related to the concept of energy as perceived by students in ascending order of difficulty is as follows: 1) energy forms; 2) transformation and transfer; 3) conservation and degradation.

Robert F. Chen, Allison Scheff, Erica Fields, Pamela Pelletier, and Russell Faux reported on "Mapping Energy in the Boston Public Schools Curriculum." After noting that the NGSS mandate of energy as a crosscutting concept facilitates a unified teaching of science, they described Energy I, "Integrating the Sciences Through Energy," at U Mass Boston, to facilitate the use of energy in teaching science in the Boston Public Schools (BPS). Its four themes are "Forms and Transformations, Systems, Conservation, and Resources," which "align well with typical energy categorization (similar to that expressed by Duit): activity/work, source/form, transfer/transformation, degradation, and conservation, with "Systems" aligning with "activity/work."

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Energy in the Next Generation Science Standards

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	HS-PS3-4	Plan and construct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system.
	HS-PS3-5	Develop and use a model of two objects interacting through electrical or magnetic fields to illustrate the forces between the objects and the changes in energy of the objects due to the interactions.
PS-PS4	HS-PS4-5	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
HS-LS1	HS-LS1-5	Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
	HS-LS1-7	Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.
*HS-LS2	HS-LS2-3	Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anerobic conditions.
	HS-LS2-4	Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
*HS-ESS1	HS-ESS1-1	Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
*HS-ESS2	HS-ESS2-4	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
HS-ESS3	HS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

A Summit for Energy Educators

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Beyond Energy I, the need to map the energy connections among the Boston Public Schools curriculum units was recognized. A group of 12 teachers, one for each grade, worked three days to develop a 105 x 105 matrix showing the 162 connections between pairs of the 105 units (of a total of 306) which contained energy concepts. The units were analyzed for their number of connections (degree centrality) and their likelihood of being in the path connecting other pairs of units (betweenness) – both indicators of playing a fundamental role in the curriculum.

The energy concepts in the eight units with the highest degree centrality are as follows:

1) The sun is an energy source transferrable by conduction, convection, and radiation. (physics, grade 9)
2) Energy can be stored and measured, is conserved when transformed. (biology, grade 8)
3) Seeds store energy. (biology, grade 7)
4) Energy is conserved and tends to disperse. (chemistry, grade 10)
5) Energy is required for phase changes. (chemistry, grade 3)
6) Energy is storable. (biology, grade 11)
7) Temperature affects density. (earth science, grade 6)
8) Matter expands when kinetic energy increases. (chemistry, grade 8)

There is a correlation of 0.84 between degree centrality and betweenness, and added to these eight units is a ninth for the greatest betweenness:

9) Organisms need energy to grow. (biology, grade 1)

The educators from Boston reported that degree centrality and betweenness are found in all grade bands (1-5, 6-8, 9-12) but are greatest for grades 6-8, showing that energy education in middle school is an important link between that in elementary and high school. They also reported that "The progression of energy themes" – "from forms and transformations to systems to conservation to resources " – "in the BPS curriculum and the NGSS are similar." (p. 148) It is also "reasonably aligned with USDOE's Essential Principles of Energy Literacy" (covered in our Spring 2012 issue). (p. 150)

Grappling in greater detail with the teaching of energy were Robin Millar, former physics and general science teacher now Professor of Science Education at the University of York, and Nicos Papadouris and Constantinos Constantinou of the University of Cyprus. Millar's presentation on "Towards a Research-Informed Teaching Sequence for Energy" began by observing that there is no broad agreement on what constitutes an appropriate understanding of energy at various educational states, partly because of the abstract nature of the concept. There is a difference between the everyday use and the scientific meaning of energy, he said; but, in agreement with Quinn, he added that the former can and should serve as the introduction of the term in the science curriculum. This is preferable to defining energy in terms of work, for this would require prior consideration of force and delay introduction of the energy concept; it would also restrict energy considerations to mechanical systems.

Millar also noted controversy about the concept of forms of energy, with some preferring to consider where energy is *stored*, while others focus on the process of *transferring*it from one place to another. He listed seven types of "energy stores" (kinetic, chemical, internal, gravitational, magnetic, electrostatic, and elastic) and four pathways of *transferal* (mechanical, electrical, heating, and radiation).

Papadouris and Constantinou went beyond their colleagues in a quest for a definition of energy. It is because energy plays a role in so many scientific processes that it is both a unifying and crosscutting concept, they began. Although students can get a kinesthetic feeling about some forms of energy, they cannot get a kinesthetic feeling for energy in *all* its ramifications, they continued. And because of this, energy as a general concept does not lend itself to an operational definition.

They thus cited epistemological barriers to defining energy as a physical quantity but argued that these barriers could be overcome by conceiving energy as a *philosophical* quantity, developing a theoretical framework to accommodate its features (conversion of form, transfer, conservation, and degradation). This is the basis of a teaching-learning model they have used to teach energy to middle school students. It begins by engaging them in aspects of the Nature of Science, to "include (i) the distinction between observations and inference, (ii) the idea that in science we often build theoretical frameworks in order to describe, interpret and predict phenomena, and (iii) the idea that it takes human creativity to invent such theoretical frameworks." (p. 211) This is followed by a second activity in which students are presented historical observations and the theories used to explain them. A final third activity asks students to reconsider how the observations in the second activity can be explained by the theoretical framework developed in the first activity.

When this sequence is used to teach energy, the first stage teaching-learning materials build a framework to accommodate "the philosophical ideas [students] are engaged with during the introduction of energy as an invented concept." (p. 212) The second stage engages students in a variety of changes in physical systems and asks

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them to explain the changes they see. The third stage asks students whether they could come up with a unified explanation of all the changes and whether energy could provide such a unified explanation. Students are asked to distinguish between transfer and forms of energy by making energy chains, with the distinction between form and transfer process emphasized by using different shapes (rectangles for forms, arrows for processes).

The degree to which the summit achieved what it had set out to do was expressed in the "Conclusion and Summary Comments" voiced by the seven editors of *Teaching and Learning of Energy in K-12 Education*. They cited that the motivation for the Energy Summit had come from the need to "bring direction to the teaching of energy" and the following among the "things learned":

1) "A fully coherent understanding of energy" can be obtained only at the nanoscopic level.
2) We need to learn more about when and how to introduce the sequence of key ideas about energy: "(i) energy forms, (ii) energy transfer, (iii) energy transformation, (iv) energy dissipation, and (v) energy conservation."
3) We need to help students relate the scientific and everyday usage of "energy."
4) Energy should be taught coherently and consistently in all subject areas in order to facilitate a unified understanding of it.
5) We need to learn from students what has facilitated their understanding of the concept of energy.
6) Professional development is needed to prepare teachers to teach about energy in a coherent and consistent way.
7) We need to learn what approaches help students rise to the next level of understanding of the concept of energy.
8) Commercial publishers and media need to facilitate relating the scientific and everyday usage of "energy."
9) Students need to see energy as a problem solving tool.

They also identified the following research needs:

1) "novel instructional approaches to teach about energy"
2) "attainable and meaningful levels of understanding of energy at different stages"
3) "comprehensive synthesis of existing research"
4) "more systematic studies examining the design of innovative curricula"
5) "reliable and valid measures of assessing student understanding"
6) "articulate[d] . . .learning progression for energy"
7) "how language affects the teaching and learning about the integrated understanding of energy"
8) "key phenomena for teaching energy as a crosscutting concept"
9) connecting "students' ideas about energy . . . to curricular interventions"
10) "plan . . . professional development experiences"

Science Education Gap

(continued from page 1)

one year, another 6% after two, and 60% remaining after eight. "The level of experience in science is the lowest in schools that most need teachers with deep expertise in teaching science to diverse students in challenging circumstances," the committee writes, adding that "many science teachers are not staying in the profession long enough to develop expertise in science teaching, a situation that requires rethinking how to support early-career teachers so that they develop as much expertise as possible, as quickly as possible." (p. 79) This is phrased more formally the second conclusion:

Conclusion 2: *The available evidence suggests that many science teachers have not had sufficiently rich experiences with the content relevant to the science courses they currently teach, let alone a substantially redesigned science curriculum. Very few teachers have experience with the science and engineering practices described in the NGSS. This situation is especially pronounced both for elementary school teachers and in schools that serve high percentages of low-income students, where teachers are often newer and less qualified.*

Regarding professional development, while there is a wide variety of professional development opportunities, the type and amount is largely up to the individual teacher, and there is "no centralized system for collecting data on teachers' professional learning opportunities," (p. 83) so the committee relied on teacher responses to the NSSME (reference cited for Chapter 3) instead. The responses in the table at the bottom of page 17 indicate that attending a workshop and participating in a learning community have been the most popular forms of professional development.

Feeling that a more organized approach to professional development is necessary to prepare teachers to implement the NGSS, the committee reached the following third conclusion:

Conclusion 3: *Typically, the selection of and participation in professional learning opportunities is up to individual teachers. There is often little attention to developing collective capacity for science teaching at the building and district levels or to offering teachers learning*

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opportunities tailored to their specific needs and offered in ways that support cumulative learning over time.

Having identified the science currently being taught in our schools and those who are teaching it, the committee turns to what teachers need to know to implement the NGSS in Chapter 5, "Science Teachers' Learning Needs." Even under normal circumstances, it is inevitable that a classroom teacher is continually learning: it is shaped by professional development opportunities, the demands of teaching responsibilities, available materials and resources, and external requirements. And to prepare to implement the NGSS all teachers have additional learning needs: knowledge, skill and competencies associated with the scientific practices, disciplinary core ideas, and crosscutting concepts of the NGSS (knowledge to transmit), and relevant pedagogical content knowledge (knowledge of how to transmit it). The committee writes that it was further "persuaded by research suggesting that teacher quality is dependent not only on individual teachers but also on their communities." (p. 94) Because "what teachers need to know about science, teaching, and students is always changing, and no one teacher will be expert in all relevant domains," (p. 94), the ability of teachers in a community to share their knowledge broadens the knowledge pool for all of them. This is the basis for the committee's fourth conclusion:

Conclusion 4: *Science teachers' learning needs are shaped by their preparation, the grades and content areas they teach, and the contexts in which they work. Three important areas in which science teachers need to develop expertise are*

- *the knowledge, capacity, and skill required to support a diverse range of students;*
- *content knowledge, including understanding of disciplinary core ideas, crosscutting concepts, and scientific and engineering practices; and*
- *pedagogical content knowledge for teaching science, including a repertoire of teaching practices that support students in rigorous and consequential science learning.*

Once we know what teachers need to know to implement the NGSS, the next step is to determine how to enable them with this knowledge. Chapter 6, on "Professional Development Programs," addresses this. Here the committee cites "five core features" which it considers to be the "consensus model of effective professional development" (p. 118): 1) content focus, 2) active learning, 3) coherence, 4) sufficient duration, and 5) collective participation. If this sounds reminiscent of our coverage of the "Grand Challenges in Science Education" in the 19 April 2013 issue of *Science* in our Fall 2015 issue, it's because this paper was written by the chair of the committee, Suzanne M. Wilson. It also forms the basis for the committee's fifth conclusion:

Conclusion 5: *The best available evidence based on science professional development programs suggests that the following features of such programs are most effective:*

- *active participation of teachers who engage in the analysis of examples of effective instruction and the analysis of student work,*
- *a content focus,*
- *alignment with district policies and practices, and*
- *sufficient duration to allow repeated practice and/or reflection on classroom experiences.*

The committee also surveyed what is known about online professional development. Although there is evidence of the efficacy of online learning, the need for effective facilitation by providers is noted. They thus reached the sixth tentative conclusion:

Conclusion 6: *Professional learning in online environments and through social networking holds promise, although evidence on these modes from both research and practice is limited.*

Because teachers spend an average of only 35 hours in formally organized professional development programs over a three-year period, most of their learning occurs either in discussions with fellow teachers or from interactions with students in their classrooms. Some call this "embedded" professional development, which for science teachers is recognized by the committee to be "both limited and diffuse" (p. 148). This is the subject of the seventh chapter, titled "Creating a Supportive Context for Teacher Learning."

Two particular opportunities for teachers to learn from each other are professional learning communities (within schools) and networks of teachers (from different schools). The learning community, which emerged in

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level	No science PD in past 3 years	At least 16 hr. sci. PD in 3 yr.	Attended a workshop	Participation in learning comm	Attendance at prof. meetings
Elementary	41%	12%	84%	55%	8%
Middle	18%	47%	91%	75%	35%
High	15%	57%	90%	73%	44%

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the 1980s and 1990s, has been found to be an effective forum for teacher learning, but little has been done to ascertain *how* this happens. A 2013 survey found that "science-related teacher study groups" exist in 32% of elementary schools, 43% of middle schools, and 47% of high schools, but only 62% had organized meeting times and only 56% had designated leaders. Skilled facilitation and administrative support are identified as contributing significantly to the success of professional learning communities. Among the networks cited as opportunities for teacher learning are those developed by the Knowles Science Teaching Foundation and the Exploratorium's Teacher Institute.

The committee also takes note of the importance of induction programs to retain new teachers and reports that 80% of first-year public school teachers and 60% of first-year private school teachers participated in them. About two thirds of these induction programs provided mentorship and collaborative planning time, and the efficacy of these programs has been clearly established.

Accordingly, the committee reached two more conclusions:

Conclusion 7: *Science teachers' professional learning occurs in a range of settings both within and outside of schools through a variety of structures (professional development programs, professional learning communities, coaching, and the like). There is limited evidence about the relative effectiveness of this broad array of learning opportunities and how they are best designed to support teacher learning.*

Conclusion 8: *Schools need to be structured to encourage and support ongoing learning for science teachers, especially given the number of new teachers entering the profession.*

The penultimate chapter, "Creating a Supportive Context for Teacher Learning," shifts from the focus on teachers in earlier chapters to what is needed to support and sustain teachers and thereby enhance student learning. It cites "five supports that must be in place at the school level to improve student learning: professional capacity, coherent instructional guidance, leadership, parent-community ties, and a student-centered learning environment" (p. 176) – from studies by Bryk, which are also cited by Suzanne Wilson, chair of the committee, in her article on professional development in the "Grand Challenges" section of the 19 April 2013 issue of *Science* (covered in our Fall 2015 issue). Schools with at least three of these five supports were ten or more times more likely to experience significant gains in math and reading, and this chapter investigates the role of three of these five supports: professional capacity, coherent instructional guidance, and leadership.

1. *Professional Capacity*.

   a. *Professional Community and Collaboration*: This is the essence of the professional learning community and requires that teachers "relinquish some of the privacy of their classrooms to engage in critical dialogue with one another." (p. 178) This sharing of experience means that not all the needed expertise must reside in one person. One way to support it is to provide time for teachers to meet together. Teachers may need the benefit of interacting with specialists or consultants with more expertise or with a professional organization like NSTA.

   b. *Staffing Policies*: Staffing schools or districts with people having needed expertise is challenging, and it occurs more frequently for mathematics than science, especially at the elementary level, perhaps because No Child Left Behind tested for math before it added science. The biggest staffing problem in high schools is out-of-field teachers.

   c. *Teacher Evaluation*: Teacher evaluations figure strongly in policies for teacher hiring, retention, and assignment, and they are increasingly playing a role of "lever for teacher development." (p. 183). Of two teacher evaluation genres – "value added" measurement and "standards-based" observations – the American Statistical Association concluded the former to be inappropriate.

   d. *Partnerships*: Partnerships that schools form with outside organizations can increase their professional capacity. Among the partnerships cited are Urban Advantage (New York City) and partnerships of the Merck Institute for Science Education (NJ and PA).

2. *Coherent Instructional Guidance*:

   a. *Curriculum Materials*: Curriculum materials can provide learning opportunities for teachers as well as students, but their use is largely up to the teachers. Teachers benefit from reading how colleagues have used a curriculum material and find that students' work reflects the structure of a model rubric that is used. Student response to rubrics "suggests that educative curriculum materials intended to support teachers in learning to engage students meaningfully in scientific

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practice integrated with science content can help them begin to do so." (p. 189) "Evidence also suggests that teachers' instructional practices in science can be shaped by their use of curriculum materials." (p. 189)

b. Assessment and Accountability: The emphasis on language arts and math testing mandated by NCLB gave science assessment a secondary role. But NGSS requires assessment of its performance objectives, to include all three of its dimensions (practices, core ideas, and crosscutting concepts). In addition to administering formative and summative assessments to their students, teachers need to be able to analyze and interpret the results.

3. Leadership:

a. Principals: As the effector of school-level change, the principal is viewed as "particularly important to education reform efforts." (p. 194) Three dimensions of a principal's leadership are highlighted: 1) *managerial* – a smoothly run office and good communications, necessary for teachers to be able to spend their time on effective teaching; 2) *instructional* – deliberate action to enhance instruction and its effectiveness, requires knowledge about learning so that instruction can be analyzed and feedback given, also deliberate orchestration of people, programs, and resources; 3) *inclusive-facilitative* – nurturing and inspiring components of the school community around a common vision.

b. Teachers: STEM teacher leaders can offset voids in a principal's knowledge of science and are all the more important at lower levels to provide mentoring, just-in-time help, and other forms of support. Literature on teacher leaders is largely descriptive and not quantitative. Teacher leader roles can be academic, administrative, policy-based, or interscholastic but are best exercised through the collaborative mode which most effectively characterizes the interaction among teachers. In fact, schools with a norm of openness and collaboration are more hospitable to the development of successful teacher leaders and schools with a non-collaborative norm are obstacles to the development of effective leadership. Support and encouragement of principals is essential for teacher leadership.

Implementation of policies requires human and physical resources, all the more so because of decimation of support agencies outside the school at the state or county level. The median spending per elementary student is only half that for middle school students and less than a third of that for high school students. "Research on the reform of instruction in mathematics and language arts has demonstrated that coaches, mentors, and school leaders are needed to work alongside teachers while they experiment and adapt to the new standards and assessments," (p. 202) and this costs money. Accordingly, this chapter is the basis for three additional conclusions:

Conclusion 9: *Science teachers' development is best understood as long term and contextualized. The schools and classrooms in which teachers work shape what and how they learn. These contexts include, but are not limited to school, district, and state policies and practices concerning professional capacity (e.g., professional networks, coaching, partnerships), coherent instructional guidance (e.g., state and district curriculum and assessment/ accountability policies), and leadership (e.g., principals and teacher leaders).*
Conclusion 10: *School and district administrators are central to building the capacity of the science teacher workforce.*
Conclusion 11: *Teacher leaders may be an important resource for building a system that can support ambitious science instruction. There is increasing attention to creating opportunities for teachers to take on leadership roles to both improve science instruction and strengthen the science teacher workforce. These include roles as instructional coaches, mentors, and teacher leaders.*

The final chapter, titled "Conclusions, Recommendations, and Directions for Research," takes the reader through a summary of chapters three through eight, in which the bases for the first eleven conclusions are developed. Someone wishing to get the gist of this report within the full context in which it was written would probably be best served reading this chapter, since only the conclusions are listed – without context – in the Summary at the report's beginning. The authors then continue as follows: "In addition to the above conclusions, all of which are drawn from chapter-specific analyses, the committee drew two additional conclusions based on the big picture emerging from these related, but separate analyses." (p. 219)

Conclusion 12: *Closing the gap between the new way of teaching science and current instruction in many schools will require attending to individual teachers' learning needs, as well as to the larger system of practices and policies (such as allocation of resources, use of time, and provision of opportunities for collaboration) that shape how science is taught.*
Conclusion 13: *The U.S. educational system lacks a coherent and well-articulated system of learning opportuni-*

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ties for teachers to continue developing expertise while in the classroom. Opportunities are unevenly distributed across schools, districts, and regions, with little attention to sequencing or how to support science teachers' learning systematically. Moreover, schools and districts often lack systems that can provide a comprehensive view of teacher learning; identify specific teacher needs; or track investments — in time, money, and resources—in science teachers' professional learning.

The emphasis in the first of these conclusions is that addressing individual learning needs also addresses the learning needs of the entire teacher workforce, with the understanding that teachers will share what they have learned with each other. The basis for the second conclusion is the inadequacy of the present educational system to match teachers with professional development that will most fully enhance the teacher workforce and enable it to implement the NGSS most effectively.

The authors then follow their annotated set of conclusions with an annotated set of recommendations. Rather than continue the present format in which teachers choose their professional development (Conclusion 3), the recommendations of the report seem to consider a teacher's professional development not as a matter of personal choice but rather what is needed for the teacher as a member of an educational community (which also includes students and administrators) to "respond to the demands placed by current reforms in science education" (p. 221) – namely, the NGSS (Conclusion 13):

Recommendation 1: *Take stock of the current status of learning opportunities for science teachers.*

Recommendation 2: *Design a portfolio of coherent learning experiences for science teachers that attend to teachers' individual and context-specific needs in partnership with professional networks, institutions of higher education, cultural institutions, and the broader scientific community as appropriate.*

Recommendation 3: *Consider both specialized professional learning programs outside of school and opportunities for science teachers' learning embedded in the workday.*

Recommendation 4: *Design and select learning opportunities for science teachers that are informed by the best available research.*

Recommendation 5: *Develop internal capacity in science while seeking external partners with science expertise.*

Recommendation 6: *Create, evaluate, and revise policies and practices that encourage teachers to engage in professional learning related to science.*

Recommendation 7: *The potential of new formats and media should be explored to support science teachers' learning when appropriate.*

In the course of writing their report, the committee often cited areas in which they felt hampered by inadequate research. The first four of their research recommendations accordingly focus on the connections between professional development and teacher learning and between teacher learning and student learning.

Research Recommendation 1: Focus Research on Linking Professional Learning to Changes in Instructional Practice and Student Learning.

Research Recommendation 2: Invest in Improving Measures of Science Instruction and Science Learning.

Research Recommendation 3: Design and Implement Research That Examines a Variety of Approaches to Supporting Science Teachers' Learning.

Research Recommendation 4: Commit to Focusing on Meeting the Needs of Diverse Science Learners Across All Research on Professional Development.

Research Recommendation 5: Focus Research on Exploring the Potential Role of Technology.

Research Recommendation 6: Design and Implement Research Focused on the Learning Needs of Teacher Leaders and Professional Development Providers.

ISTE issues new Standards for Students

The International Society for Technology in Education (ISTE) has recently issued new Standards for Students, the result of input from more than 2700 people from 52 countries, including some 300 students. "Supporting a learner -driven approach, the 2016 ISTE Standards for Students are a blueprint by and for innovative educators worldwide to guide education transformation and meaningful, future-ready learning," according to a news release. "They are not about devices or using technology; they are about giving voice to learners the world over and ensuring that learning is a student -centered process of exploration and discovery." The complete standards can be obtained from the ISTE website, <iste.org>.

NSB issues Science and Engineering Indicators for 2016

Every other year the National Science Board issues its *Science and Engineering Indicators* (*S&EI*). This report presents data collected from every facet of science and engineering, from the preparation of scientists and engineers to their practice and the public's understanding of what they do. These data are grouped into seven chapters, each of which is further divided into subtopics. A summary for each subtopic is given as follows:

Chapter 1: "Elementary and Secondary Mathematics and Science Education"

Student Learning in Mathematics and Science. NAEP (National Assessment of Educational Progress) scores through 2013 have shown slight improvement but still less than 50% proficiency. PISA (Program for International Student Assessment) scores show that U.S. scores continue to be lower than many other nations. Racial and ethnicity gaps have narrowed slightly but persist. Parental education and economic background are seen to make a difference.

High School Course Taking in Mathematics and Science. A survey of high school juniors in 2012 showed that 69% of them were enrolled in a math course at the level of Algebra II or greater (with Geometry ranking below Algebra II; for 63.5% of Asian students it was "greater"). Of the juniors surveyed, 39% had taken biology as freshmen, and 41% of this cohort was now enrolled in either basic chemistry or physics, while another 20% were taking advanced science courses. Advanced Placement course enrollment had almost doubled in a decade (273,000 in 2003 to 527,000 in 2013), but only 17% of high school graduates took the AP Exam and only 10% passed. The greater the high school grade point average and the higher the highest level math course, the greater the likelihood that a high school graduate would choose a STEM major in college.

Teachers of Mathematics and Science. Of middle and high school math teachers, 91% were certified in 2011, up 6% since 2003; 85% of them had more than three years of experience, and 56% had master's degrees. For science teachers, 92% were certified in 2011, up 9% since 2003; 90% of them had more than three years of experience, and 61% had master's degrees. With high-poverty schools defined as those with at least half the students eligible for free/reduced price lunch, and high-minority schools defined as those with at least 45% nonwhite enrollment, it was found that these schools had a lower percentage of math and science teachers with master's degrees, certification, and more than three years of experience. Teachers in these schools were also paid less: $10,000 less for math teachers, $13,000 less for science teachers. Teachers at these schools also felt that student attendance and behavior interfered with teaching at about twice the rate in low-poverty and low-minority schools.

Instructional Technology and Digital Learning. More than half the teachers reported an inadequate number of computers. On the other hand, the number of full-time online enrollments increased 50% from 2009-2010 to 2013-2014.

Transition to Higher Education. The 2012 on-time graduation rates were 78% (male), 85% (female), 93% (Asian), 85% (white), 68% (African-American), 76% (Hispanic), 68% (Native American), compared with an OECD average of 84%. The percentage of American high school graduates moving on to college increased from 51% in 1975 to 66% in 2013, but the 2013 percentage was significantly smaller for students from low-income families or families whose parents had less than a high school education. The 71% American young adult college enrollment rate is greater than the 58% which characterizes OECD countries.

Chapter2: "Higher Education in Science and Engineering"

The U.S. Higher Education System. Research universities awarded 73% of U.S. S&E doctorates, 41% of S&E master's degrees, and 37% of S&E bachelor's degrees. While "bachelor's colleges" accounted for only 11% of S&E bachelor's degrees, these graduates later went on to account for 14% of the S&E doctorates. Similarly, while the proportion of Hispanics and African-Americans earning S&E bachelor's degrees from predominantly Hispanic and historically Black institutions has declined, graduates of those institutions accounted for 30% of the doctorates earned by Hispanics and 25% of the doctorates earned by African-Americans. Tuition at public research universities nearly tripled, as state and local appropriations declined.

Undergraduate Education, Enrollment, and Degrees in the United States. The number of S&E bachelor's degrees has increased but has remained about 37% of all bachelor's degrees, with more men in engineering, computer science, math, and physics, more women in biology, agriculture, and social sciences (which are included in S&E for the purpose of this report). The female share of computer science majors has dropped since 2003. Trying to ascertain the reason for this has unearthed the realization that women are more comfortable getting peer support from other women. Adding social relevance and real world applications to courses has also been found to help retain women's interest in computer science. A larger percentage of S&E bachelor's degrees has been awarded to Hispanics (up from 7% in 2000 to 11% in 2013), but the percentage of S&E bachelor's de-

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grees awarded to African-Americans has remained flat at 9%.

Graduate Education, Enrollment, and Degrees in the United States. The number of S&E graduate students increased by 18% in 2013-2014. The growth in the number of S&E master's degrees awarded was 73% from 2000 to 2013, greater than more than 54% growth for bachelor's degrees and 47% for doctorates. The number of S&E master's degrees awarded to Hispanics and African-Americans doubled during this time, while the increase for whites was only 50%. The number of doctorates awarded to Hispanics and African-Americans also doubled during the same time. The median number of years from entering graduate school to receiving a S&E doctorate has decreased from its peak of 7.2 years at the beginning of the century.

International S&E Higher Education. In 2012 the U.S. awarded more S&E doctorates than any other country, and 37% of them in 2013 went to international students. More knowledge-based economies in Asia have led Asian countries to increase their own higher education system. The following comparison between the U.S. and China is instructive: The number of bachelor's degrees in natural science and engineering in the U.S. increased from 200,000 in 2000 to 300,000 in 2012; the corresponding number of doctorates was 17,500 and 27,000. The number of bachelor's degrees in natural science and engineering in China increased from less than 300,000 in 2000 to more than 1,300,000 in 2012; the corresponding number of doctorates was 7000 and 30,000.

Chapter 3: "Science and Engineering Labor Force"

U.S. S&E Workforce: Definition, Size, and Growth. Three definitions of the S&E workforce are given: 1) the number of workers in S&E occupations (the National Science Foundation lists 5.7 million with bachelor's degrees or higher, and the Census Bureau lists 4.6 million for the same category, but 6.2 million for *all* educational levels, which would include Associate's degrees); 2) holders of S&E degrees (21.1 million with *some* S&E degree); 3) workers who use S&E expertise on their job (17.7 million). (S&E "occupations" do not include those in S&E-"related" fields, which include health-related occupations, precollege math and science teaching, S&E technicians and technologists, and architects.) The S&E workforce is growing faster than the overall workforce and is also better educated (75% have a bachelor's degree or higher).

S&E Workers in the Economy. Of the identified 23.7 million employed scientists and engineers, 70% are employed in business, 19% in education, 11% in government, though for doctorates it's 45% in business, 45% in education. The percentage working in the field of their S&E highest degree is also highest for doctorates, while the percentage of S&E highest degree holders in non-S&E occupations ranges from 27% (engineering) to 80% (social sciences). The percentage of S&E workers varies for different types of business (4.7% overall, from 0% in food services to 24% in professional, scientific, and technical services) and different parts of the U.S. (with a high of 16.8% in San Jose-Sunnyvale-Santa Clara, CA).

S&E Labor Market Conditions. The unemployment rate of S&E workers is less than half that of the total U.S. labor force. This is uniform in all S&E fields, reaching a minimum between 15 and 19 years after receipt of the highest degree. Salaries of S&E workers are also about twice those of the overall workforce (perhaps in part because these workers are also better educated?).

Age and Retirement of the S&E Workforce. The median age of the S&E workforce has increased from 41 in 1993 (with 20% of the workers between 51 and 75) to 43 in 2013 (with 34% of the workers between 51 and 75), but the percentage working full time decreases in the early 60s.

Women and Minorities in the S&E Workforce. Although women are half the college-educated workforce, they comprise only 29% of the S&E workforce, with the lowest percentage (15%) in engineering. The following table shows trends in the racial/ethnic composition of the S&E workforce and how it compares with the general population:

Group	%S&E workforce(1993)	%S&E workforce(2013)	%US population(2013)
Native American	0.2	0.2	0.6
Asian	4.1	17.4	5.2
African-American	3.6	4.8	11.7
Hispanic	2.9	6.1	14.6
White	84.1	69.9	66.2

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But because the percentage increase of white women was outpaced by the percentage increases of African-Americans and Hispanics, white women now comprise a smaller percentage of the S&E workforce:

Group	%women in S&E workforce(1993)	%women in S&E workforce(2013)
Asian	9.3	17.7
African-American	5.7	6.6
Hispanic	3.2	6.9
White	81.5	66.9

Also of interest is a comparison of median annual salaries paid the various groups in the S&E workforce:

Group	Median annual salary (2003) ($K)	Median annual salary (2013) ($K)
All	60	72
All men	68	80
All women	45	55
Native American	48	68
Asian	64	80
African-American	48	58
Hispanic	50	59
White	60	74

Immigration and the S&E Workforce. Foreign-born workers generally are overall better educated. Twenty percent have doctorates compared to 10% of Americans. About a third are from China and India.

Global S&E Labor Force. The S&E workforces in the US and the European Union are growing steadily but are being outpaced by those in China and South Korea. Japan's S&E workforce is rising only slightly, and that in Russia is declining.

Chapter 4: "Research and Development: National Trends and International Comparisons"

Recent Trends in U.S. R&D Performance. The performance of R&D in the U.S. in 2013 was done mostly by business (71%), the rest by academic institutions (14%), the federal government (11%), and nonprofit organizations (4%). The business R&D was more D than R (88% of the total D), while the academic R&D was more R than D (51% of the total R). The funding of R&D in the U.S. in 2013 was also done mostly by business (65%), the rest by the federal government (27%), nonprofit organizations (4%), and academic institutions (3%). Flat in 2008-2010, the U.S. R&D funded by business and the federal government increased in 2011-2013. Historically, the percentage of U.S. R&D funded by business has increased since a 1963 minimum, while the percentage funded by the federal government has decreased since a 1963 maximum (the two percentages were equal in 1980).

Cross-National Comparisons of R&D Performance. The U.S. continued to be the leading nation in R&D in 2013 with $456.1 billion, 27% of the total, but China comes close behind with 20%, followed by Japan with 10% and Germany with 6%. But regionally, Asia leads the world with 40% of the world's total R&D, followed by North America with 29% and Europe with 22%. China's R&D expenditures in 2013 have accelerated to almost match those of the EU.

U.S. Business R&D. Five industries – chemicals (especially pharmaceuticals), computers and electronic products, transportation equipment, information, and professional, scientific, and technical services – performed 82% of the business R&D in 2013 (about the same as 84% in 2008). Business funded 82% of their R&D with the federal government being the biggest funder of the rest.

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Recent Trends in Federal Support for U.S. R&D. The Department of Defense has historically accounted for more than half of federal R&D funding, and most of the non-defense R&D has been health related. These two major sources of federal R&D funding have borne most of the cutbacks in federal R&D funding since 2010, as can be seen in the following 2014 percentages of federal R&D funding: 49% from the Department of Defense, 23% from Health and Human Services, 8% from NASA, 8% from the Department of Energy, 4% from the National Science Foundation, and 2% from the Department of Agriculture.

Federal Programs to Promote the Transfer and Commercialization of Federal R&D. The federal government actively seeks (through a wide variety of legislation) to transfer the results of the R&D it funds for gains in the American economy.

Chapter 5: "Academic Research and Development"

Expenditures and Funding for Academic R&D. Adjusted for inflation, academic R&D expenditures (95% of which were for S&E) decreased 1% from 2103 to 2014. The federal government's 58% share in 2014 represented a decrease, but academia's 22% share represented their largest percentage contribution so far. An additional 6% of academic R&D funding in 2014 came from each of the following: state and local governments, nonprofit organizations, and business. The bulk of the federal funding (92%) for academic R&D in 2014 came from the same six agencies which account for most R&D in general, although with different percentages: HHS (54%), NSF (13%), DOD (13%), DOE (5%), NASA (4%), USDA (3%). Public universities relied more on state and local government and their own funds, while private universities relied more on the federal government for R&D funds. While emphasis on R&D support had shifted from the physical sciences to the life sciences, funding for engineering R&D is now increasing more than that for the life sciences. Additional R&D expenditures supported by the American Recovery and Reinvestment Act of 2009 peaked in 2011 but had dwindled to a trickle by 2014; they account for a "bubble" at 2011 in the graph of federal academic S&E R&D expenditures.

Infrastructure for Academic R&D. Infrastructure for academic R&D consists of laboratory space and laboratory equipment to put in it. Also important is the information technology needed to support the R&D. Universities bear the major cost for their laboratories (more than 60%). Less than 10% is provided by the federal government, although the federal government has typically funded more than half the cost of laboratory equipment. That percentage fell below half (to 45.1%) in 2014 for the first time since records were begun in 1981.

Doctoral Scientists and Engineers in Academia. The percentage of holders of S&E doctorates with full time faculty positions decreased from about 90% in the early 1970s to about 70% in 2013, while the percentage with "other" full time positions in academia increased from about 7% to about 19% in the same time frame. The percentage of tenured positions in the doctoral academic workforce decreased from 53% in 1997 to 47% in 2013, but the percentage of tenure track positions has held steady. In 2013 43,000 holders of S&E doctorates were employed as postdocs, accounting for 42% of US-trained holders of S&E doctorates less than four years beyond their doctorate, while less than 29% of the same pool had full time faculty positions. Seventeen percent of US-trained holders of S&E doctorates were still employed as postdocs from four to seven years beyond their doctorate. In addition of a redistribution of holders of S&E doctorates in academia, there was also a change in how full time S&E doctoral faculty viewed their work. In 1973 67% considered their primary work to be teaching; this decreased to 53% in 1993 and to 46% in 2013. In 1973 19% considered their primary work to be research; this increased to 33% in 1993 and to 36% in 2013.

Outputs of S&E Research: Publications and Patents. The 1,117,866 S&E publications in 2003 almost doubled to 2,199,704 in 2013. In the U.S., Japan, and EU, most of this increase was due to biological and medical science, but in China it was due mostly to engineering (37% of all engineering publications for the entire world). The U.S. still led the world in S&E publications in 2013, though its percentage had dropped from 26.8% in 2003 to 18.8%, barely ahead of second place China at 18.2%, almost tripled from 6.4% ten years earlier. China was not the only Asian country to show this kind of growth. Sixth place India increased its percentage of S&E publications from 2.3% in 2003 to 4.2% in 2013, and ninth place South Korea increased its percentage from 2.0% to 2.7%. More astoundingly, Iran, now in sixteenth place, increased its percentage from 0.3% to 1.6%, which resulted from a 9.5-fold multiplication in its number of publications; and Malaysia, in twenty-second place, showed a 13.3-fold multiplication in its number of publications in the same decade. An increased number of S&E publications also showed multiple authorship, including co-authorship from researchers in different countries (this accounted for 13.2% of S&E publications in 2000 but 19.2% of S&E publications in 2013). While the number of S&E publications subsequently cited by S&E publications from other countries generally increased, this was not true for China, suggesting that China's increased publication output is used mostly within China. Russia also experienced a decreased number of citations of its publi-

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cations from other countries; this is believed to parallel its decreased S&E workforce.

In 2013 inhabitants of the U.S. generated 412,542 S&E publications and were awarded 138,496 patents (but only 5990 to academia). In 2014 72,435 patents cited 302,485 S&E articles, 54% foreign and 44% from the U.S., a trend reflecting internationalism and the number of patents awarded to applicants outside the U.S. and the increasing number of articles published there. Since the two leading categories of patents that year were pharmaceuticals (16%) and biotechnology (13%), it should be no surprise that 34% of the cited articles were in biological sciences and 22% were in the medical sciences. Another 12% of the cited articles came from each of the two fields of computer sciences and engineering. *S&EI 2016* calls special attention to 3.4% of the patents in the four categories of alternative energy, pollution mitigation, smart grid, and energy storage, because these categories reflect the "capacity of the U.S. S&E enterprise to address large-scale challenges." (p. 5-123)

Chapter 6: "Industry, Technology, and the Global Marketplace"

Knowledge and Technology Infrastructure in the World Economy. In 2014 five knowledge-intensive (KI) industries – business, finance, information, education, and health – accounted for 26% of the world's gross domestic product (GDP). The first three of these are known as commercial KI industries and account for 17% of the world's GDP. Five high technology (HT) manufacturing industries – aircraft and spacecraft, communications and semiconductors, computers, pharmaceuticals, and testing, easuring, and control instruments – accounted for 2% of the world's GDP. Of these industries, information, communications and semiconductors, and computers are collectively considered to be information and communications technology (ICT). ICT and education are considered to be the key components of the knowledge and technology infrastructure. The contribution of knowledge and technology-intensive (KTI) industries, amount spent on education, and amount spent on ICT are tabulated as percentages of GDP for several selected countries, in the table at the lower right corner of the page.

There seems little correlation between the fourth column and the others, because some developing countries spend even more of their GDP on ICT than developed countries.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries. A third of the worldwide GDP from commercial KI industries comes from the U.S., with the EU in second place at 25%, and China a distant third at 10%, although China, India, and Brazil are listed as up-and-coming countries on this list. Where China has been making strides has been in HT manufacturing – from 2003 to 2014 its worldwide share has gone from 7% to 27% of the world GDP, while that of the US has declined from 36% to 29%, that of the EU from 23% to 17%, and that of Japan from 16% to 5%. The US lead in HT manufacturing arises from its aircraft and spacecraft (52% of world GDP) and its testing, measuring, and control instruments (42%) industries. China's strength comes from the ICT (39%) and pharmaceutical (28%) industries (China manufactures generics), and the Philippines are cited as an up-and-coming alternative location for manufacturing these items. Although China is the destination for final production in the ICT industry, China is also limited there because some of the parts it assembles are imported (from such countries as Germany, South Korea, and Taiwan).

The U.S. is seen to be in a position of relative economic strength relative to the EU and Japan because of its greater success in recovering from the global recession. Its KI industries employ 20 million workers and conduct 29% of U.S. business R&D. Its HT manufacturing sector employs 1.8 million workers and conducts about half of U.S. business R&D. But this last number is down from 2.0 million workers in 2008, and since the HT manufacturing sector has resumed producing at its pre-recession level, this means that the remaining workers have become that much more productive and that the lost jobs will not return.

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Country	%GDP from KTI industries	%GDP spent on education	%GDP spent on ICT
U.S.	39	5.0	4.9
U.K.	37	5.5	3.2
Australia	33	4.3	2.2
Japan	30	3.3	3.9
EU(France/Germany)	30	4.8/4.0	3.1/2.8
Turkey	24.5	3.1	4.1
South Korea	24	4.2	3.2
China	20.5	3.0	4.9
India	19.5	2.6	3.7
Brazil	18	3.7	2.4
Indonesia	12	0.8	4.7

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Trade and Other Globalization Indicators. The focus of *S&EI 2016* on trade in KTI industries is on four services (communications, computer and information, finance, and other business) and six HT products (aerospace, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments). The export of 44% of all commercial KI services has a value of $1.6 trillion per year, and in 2013 the EU was lead exporter (31% of the total), followed by the U.S. (17%) and China and India (7% each). (In 2004 the EU and the U.S. each accounted for 2% more of the total, and China and India only 4% each.) The value of the HT exports (12% of the total of exported manufactured goods) was $2.4 trillion, $1.3 trillion of which consisted of ICT products. The leading exporting country in 2014 was China (with 24%), but a selected group of other Asian countries (Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand) topped this with 26%. The EU accounted for 18%, the U.S. for 12%, and Japan 6%. In 2003, the group of Asian countries had an even larger share, 30%, twice that of China, while Japan accounted for 13%. The U.S. (15%) and EU (19%) also had larger shares of HT exports in 2003.

Innovation-Related Indicators of the United States and Other Major Economies. *S&EI 2016* accepts the OECD definition of innovation as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method." (p. 6-62) Based on this definition, the five HT manufacturing industries already cited as accounting for 2% of the world's GDP reported product innovation at at least twice the rate of the US manufacturing sector. And 69% of software firms reported introducing new products or services as opposed to only 9% of other non-manufacturing companies. Although patents suggest innovation, they do not correlate one-to-one with it. Yet *S&EI 2016* presents data on the distribution of recipients of U.S. and triadic (applicable in the U.S., the EU, and Japan) patents. In 2014, American inventors received 48% of U.S. patents, those from Japan 18% and those from the EU 15%, down, respectively, from 52%, 21%, and 17% in 2003, while an increasing share of U.S. patents went to inventors from South Korea (5.5%), Taiwan (3.8%), and China (2.7%). Japan has steadily held the lead at 31% in triadic patents, followed by the EU and U.S. at 27% in 2012, down from 30% and 29%, respectively, in 2003. During this decade, South Korea increased its share from 4% to 6%, and China quadrupled its share to 4%. The U.S. led the world in income from the export of royalties and fees at 50% in 2013 (down from 54% in 2003), followed by the EU (21%, down from 20%), and Japan (11%, down from 12%). And the U.S. also led in venture capital attracted in 2014 with $49 billion, followed by China at $13 billion, the EU at $9 billion, and India at $5 billion.

Investment and Innovation in Clean Energy Technologies. This section focuses on the four categories of alternative energy, pollution mitigation, smart grid, and energy storage, whose patents are considered at the end of Chapter 5, a group of categories collectively referred to as clean energy technology. Global government investment in the research, development, and demonstration (RD&D) of these technologies totaled $12.7 billion in 2013, with the EU leading at $4.4 billion (but down from a peak of $5.8 billion in 2011), followed by the US at $3.5 billion, Japan at $2.6 billion, and Canada and Australia at $0.8 billion each. This was dwarfed by the private investment in clean energy technologies, which grew to $281 billion in 2014, with China leading with $86 billion, followed by the EU at $51 billion, the U.S. at $40 billion (down from a peak of $57 billion in 2011), and Japan at $35 billion. About half of this was devoted to solar energy, and another 35% to wind energy. Renewable energy generation, nearly constant at 1700 gigawatts (GW) from 2004 to 2007, had grown to nearly 2000 GW by 2013, but about half of this has continued to be from hydroelectricity. The biggest growth has been from wind, followed by that for solar. (For reference, 1 GW is the power generated by a standard electric power plant.) The patents cited at the end of Chapter 5 are distributed among the four clean energy technology categories as follows: alternative energy (3500), pollution mitigation (2400), smart grid (1300), and energy storage (1700).

Chapter 7: Science and Technology: Public Attitudes and Understanding

Interest, Information Sources, and Involvement. Of those polled about their interest in new scientific discoveries, new medical discoveries, new inventions and technologies, environmental pollution, and space exploration, all the categories except space exploration showed more than 40% "very interested" and less than 20% "not interested at all." Except for a slight increased interest in new inventions and technologies and a slight decreased interest in environmental pollution, these levels of interest have changed little since 2008. Extensive data list the amount of time devoted by network nightly news broadcasts devoted to science and technology (S&T), but the reality is that the percentage of Americans obtaining their S&T news from these broadcasts has declined, from 44% in 2001 to 28% in 2014, while the Internet has shown a steady growth, from 9% in 2001 to 47% in 2014. Newspapers have also declined as the primary source of S&T news – from 17% in 2001 to 7% in 2014.

Public Knowledge about S&T. Public knowledge about S&T is gauged by response to a set of nine true-false questions, five of which ask about factual information in physical science, two about factual information in biological science, and two reflecting understanding of scientific inquiry (one about the consequences that one in four children will inherit an illness, the other about the design

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of a drug trial). The average score of 5.8 out of 9 (64%) is one which has been relatively unchanged since this testing began in 2001, although there is a correlation with educational attainment, from 47% for those not completing high school to 81% with a graduate professional degree. The EU scores comparably but the rest of the world does not score as well (perhaps this is a consequence of recommended resource #14 of our Fall 2008 issue, Art Hobson, "The Surprising Effectiveness of College Scientific Literacy Courses," *Phys. Teach*, **46**, 404-406 (Oct 08)). In addition to these nine questions, two additional ones are asked – about the origin of the universe and the theory of evolution. The larger number of correct answers resulting when these questions are prefaced by "according to astronomers/the theory of evolution" has already been noted; *S&EI 2016* reports that replacing the question about the evolution of humans by one about the evolution of elephants has a similar effect in divorcing knowledge about evolution from belief in it. A final question asks opinion about astrology, and the 2014 polling found 65% rejecting it as "not at all scientific," up from 55% in 2012.

<u>Public Attitudes about S&T in General</u>. In addition to public knowledge of S&T, the public perception of it is also significant, especially when it comes to funding scientific research. In general, the American perception of S&T is quite positive. Strongly supporting the belief that the benefits of scientific research outweigh its harms are 43% of Americans, and another 26% who support this believe "slightly." This combined 69% supporting the belief that the benefits of scientific research outweigh its harms is at the low end of the range of 68%-80% which have supported this belief since the 1970s. The comparable numbers in Europe are 60% ("strong") and 17% ("slight"). A larger percentage of Americans believe that S&T will create more opportunities for future generations: 33% strongly, and 56% normally. The corresponding European number (overall) is 75%. The percentage of Americans supporting government funding of scientific research is also high, 25% doing so strongly and 60% normally, essentially the same percentage since 1985, varying from 75% for those not completing high school to 90% for those with graduate degrees. The gap between those who believe too little rather than too much is spent on scientific research has widened – from 30% (too little) rather than 20% (too much) in 1981 to 40% rather than 10% in 2014. Yet there are other issues that larger percentages of Americans would like to see funded more: 74% would fund education more, 60% the environment, and 57% health. In spite of their support of S&T, 11% of Americans strongly (and 40% normally) feel that science is making life change too fast, with the overall comparable number in Europe being 62%. Yet Americans show confidence in their scientific community that is exceeded only by their confidence in the military: 41% express "high" confidence in the scientific community and 49% express "some" confidence, with the corresponding percentages for the military being 49% and 42%, respectively. Close behind in the list of communities meriting high confidence is the medical community, for which the percentages are 37% and 52%. (In contrast, the confidence percentages for Congress are 5% and 38%.) It is interesting to note that the military has led S&T and medicine in confidence from the American public only since 2002.

<u>*Public Attitudes about Specific S&T-Related Issues*</u>. Sometimes the public attitude about S&T-related issues deals with the issues on a stand-alone basis; sometimes it prioritizes one S&T-related issue above another. Although concern about most specific environmental issues decreased in 2015 from a peak in 2014, half of American prioritized the environment over the economy in 2014, up from 43% doing so in 2012, but down from 71% in 1990. Almost half (49%) also prioritized the environment over energy in 2015, up from 41% in 2011 but down from 58% in 2007. Priorities were also expressed among various approaches to energy. The percentage prioritizing conservation over fossil fuels in 2014 was 57%, up from between 48% and 51% since 2010 but down from 64% in 2007. Between 60% and 64% prioritized alternative energy over fossil fuels in 2014, up from between 47% and 54% in 2012-2013 but down from between 63% and 66% in 2011. Critical news events affect public attitudes about S&T-related issues. Support for nuclear energy peaked at 62% in 2010 but declined after the Fukushima Daiichi nuclear accident to 51% in 2015. Likewise, the *Deepwater Horizon* spill in 2010 caused the percentage favoring offshore drilling for fossil fuels to decrease from 68% in 2009 to 44% in 2010. The percentage favoring hydraulic fracturing ("fracking") is decreasing as well – from 44% in early 2013 to 37% in 2014. The percentage of Americans "worried" about climate change in 2015 is a majority, 55% (32% a great deal, 23% a fair amount), but not as great as the 63% worried in 1989 (35% a great deal, 28% a fair amount), although only 37% in 2015 believe that it threatens their life. A similar percentage, 59% (27% extremely and 32% very much so) believe that climate change is occurring, and a comparable percentage believe that there is a scientific consensus about climate change. Other S&T-related issues for which *S&EI 2016* has meaningful data to present are stem cell research and animal testing. A majority of 65% of Americans saw embryonic stem cells research as "morally acceptable" in 2014, up 5% from the year before, and 13% support human cloning. The percentage favoring medical testing on animals is decreased to 57% in 2014 from 65% in 2001, according to Gallup, 47% in 2014, down from 52% in 2009, according to Pew.

The easiest way to access *S&EI 2016* online is to "google" it.

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Eric Plutzer, Mark McCaffrey, A. Lee Hannah, Joshua Rosenau, Melinda Berbeco, and Ann H. Reid, "Climate Confusion Among U.S. Teachers," *Science*, **351**, 664-665 (12 Feb 16).

A survey of a representative sample of 1500 public middle and high school science teachers from all 50 states shows that 70% of middle school science teachers and 87% of high school biology teachers devote at least an hour to global warming. But not all of them bring up the role of humans in causing climate change, and some see it as an issue to teach "both sides" of. A teacher's political or cultural background was found to factor in whether and how (s)he taught about climate change. Only 4.4% reported pressure *not* to teach about climate change. Because developments in climate science outpace textbooks and teacher training, the need to provide teachers with up-to-date teaching materials, especially to enable them to respond to student questions, is cited.

2. Bureau of Land Management, *Solar-Generated Electricity*, available online at <blm.gov/style/medialib/blm/wo/Law_Enforcement/ncls/education_interpretation/spotlight_photos.Par.26483.Filedat/ciSolar120815.pdf>

This 28-page booklet contains three lessons related to the generation of solar energy on public lands managed by the BLM, with special focus on the Ivanpah Concentrating Solar Power system on more than 3400 acres of California desert in which 170,000 heliostats concentrate sunlight to generate 379 MW and the Desert Sunlight photovoltaic array of 8 million modules on 4100 acres of California desert which generates 550 MW. In the first lesson students learn about these systems from You Tube. They also learn that every MWh of electrical energy generated by the Sun avoids 2249 lb. of carbon dioxide had it been generated by coal or 1135 lb. of carbon dioxide had it been generated by natural gas, also that the percentage of solar-generated electricity increased from 0 in 1990 to 0.4 in 2014 (during which time wind-generated electrical energy increased from 0 to 4.4%). Their understanding can be assessed by a set of questions, one of which requires a ratio and proportion calculation.

In the second lesson students discuss the effect of solar -generated electrical energy on recreation, tourism, scenery, birds, the desert tortoise, power transmission, and cost (with the Ivanpah system again cited as an example) and fill out a quantitative grid evaluating electrical energy generation by Concentrating Solar Power systems, photovoltaic arrays, coal, and gas, according to the criteria considered. In the last lesson students in groups representing one of each of seven different points of view present to the BLM reasons they should approve or not approve an application for a Concentrating Solar Power system or a photovoltaic array.

3. S. Ananthanarayanan, "Flitting to green energy," *The Statesman* (Kolkata), 16 (5 Aug 15).

A group at the University of Exeter has found that *Pieris* butterflies warm their thorax by putting their wings in a V-formation toward the Sun. The wing material arranged conically around a photovoltaic cell increased incident sunlight by 42.3% and did so by a quasi-random pattern of beads of pterin. A regular pattern of beads concentrates sunlight of some but not all frequencies, and a random pattern has no effect. Creating the quasi-random pattern of butterfly wings is impractical, but a group from Northwestern University found that the pits and lands on Blu Ray discs show a quasi-random pattern.

4. S. Ananthanarayanan, "Doubling the mileage factor," *The Statesman* (Kolkata), 16 (19 Aug 15).

Photons in the visible range (between 350 and 600 nm) cannot be absorbed by silicon in photovoltaic cells, so a dyed gel of albumin and coconut oil is used to absorb these photons and have their energy transformed to absorbable longer wavelengths via Förster Resonance Energy Transfer.

5. S. Ananthanarayanan, "Better managing the sun's energy," *The Statesman* (Kolkata), 16 (23 Sep 15).

A group from Stanford University found that covering a doped silicon photovoltaic cell with silica reduced the operating temperature of the cell and increased its efficiency. This was enabled by silica's radiating in the 8 – 13 micron range, which is not absorbed by the atmosphere and thus results in complete cooling.

6. Richard Monastersky and Nick Sousanis, "The fragile framework," *Nature* (24 Nov 15).

These authors tastefully employ a graphic format to provide a comprehensive and informative background leading to the Paris Conference to limit greenhouse gases which would be especially effective with high school students.

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REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Andrea Pagnoni and Stephen Roche, *The Renaissance of Renewable Energy* (Cambridge, New York, 2015). x + 294 pp. $29.99. ISBN 978-1-107-69836-9.

I was intrigued by the title of this book because of all I had been reading about positive developments in the extraction of energy for humans from the Sun and wind – I was hoping to see these developments put into a systematized perspective. My appetite was further whetted by these opening words from the authors: "Whether one views climate change, population growth or resource depletion as the greatest threat to human survival, the basic problem is the same: there are limits to what our planet can provide or absorb. The renaissance of renewables is inevitable because sooner or later the oil, gas and coal will run out." (p. 1)

What I got instead was a general book about energy, with the first chapter describing how the energy concept was first formulated in terms of work as the product of force and distance and tracing the role of energy in history through the twentieth century. This was followed by chapters on forms and sources of energy, relative amounts of energy "used" for different purposes, the politics and economics of energy, and the environmental costs of "using" it. In the middle of these the longest chapter of the book describes all the specific sources of energy, including all the renewables. This chapter left me with the feeling that there's lots of energy out there, but it's not sufficiently concentrated to be accessed efficiently.

This characterizes renewable energy, the ostensible topic of this book, and the penultimate chapter leads to the same place. Echoing the enticing quotation from the first page of the book, it observes that twentieth century improvements in the quality of human life have come at the expense of Earth's ecosystems, but this cannot continue indefinitely. This sets us up for finding sustainable ways to enhance our quality of life in the final chapter, which asserts that extricating ourselves form carbon-based energy and developing sustainable societies requires "the audacity . . . to explore the outer reaches of the possible rather than the near shores of the probable." (p. 242)

The authors do this in the context of a plan by Mark Jacobson and Mark Delucchi whereby 0.59% of Earth's land surface provides the world's energy – 51% from wind, 40% from solar, and 9% from tidal, geothermal (baseload) and hydro (peak load). Along with the transition to renewables is a requirement for greater efficiencies. For vehicular transportation, this means changing from the internal combustion engine to the electric motor, and the environmental consequences will depend on the energy source of the electricity. The only combustible fuel for transportation (presumably in the air) would be hydrogen. All new energy would be from renewable sources by 2030 and *all* energy would be from renewable sources by 2050. Thus in this book "the renaissance of renewable energy" is yet to come, although the authors note that the International Energy Agency revised its projected percentage of total energy from renewables in 2030 up from 14% to 25%.

I would like to close this review with two side comments, one negative and one positive. I would point out that neither of the authors has a background in physics (Pagnoni is an ecologist/environmentalist and Roche an editor/translator), and their book is punctuated with errors related to physics. Astute physicists will recognize these, but I am concerned that lay readers (who would seem to constitute the bulk of this book's audience) would not. The most serious errors are characterizing energy by "force, work, and power" (p. 6), understating the intensity of solar radiation by a factor of 100 (p. 11), stating that uranium "sheds neutrons" because it "has so many protons" (p. 36), implying that energy is stored in chemical bonds (p. 70), connecting photovoltaic panels with the same voltage in series (they should be in parallel!) (p. 113), and stating that the Energy Return On Investment of fossil fuels will increase as their supplies dwindle (p. 248). On the positive side, I would also point out that the authors have been very generous in providing photographs, graphs, and tables to supplement their text in making their points.

\- John L. Roeder

(*Editor's Note*: The preceding review was originally written for the American Physical Society's publication, "Physics and Society.")

PICTURE YOUR BOOK REVIEW HERE!

Have you read a good book relating science to society? Why not review it for the *Newsletter*?

Then send it to the Editor-in-Chief at JLRoeder@aol.com

It will be gratefully appreciated.

Clearinghouse Update

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

Still More on Reactor Design

The article in our Fall 2015 issue on the dismal prospects for the future of nuclear energy, in its coverage of Charles Ferguson's online report, *Moving Advanced Nuclear Energy Systems to Global Deployment*, cites six nuclear design alternatives to today's light water reactors, which were adapted from the reactors first designed for nuclear submarines and aircraft carriers. In *Physics Today*'s online newsletter, Cheryl Rofer, retired from working as a chemist at the Los Alamos Nuclear Laboratory, reported the results of her research into what happened there after the first nuclear submarines, aircraft carriers, and power plants, all based on the light water reactor design, were commissioned in the 1950s, under the leadership of Admiral Hyman Rickover.

The focus of Rofer's research was Milton Shaw, a protégé of Admiral Rickover and the leader of the team which adapted the naval reactor design for use at the first nuclear power plant at Shippingport, PA, commissioned in 1958. In 1964 Shaw became director of the Reactor Development and Testing Division (RDTD) of the Atomic Energy Commission (AEC). At that time, Rofer reports, the AEC's national laboratories (including Los Alamos) were testing "a wide variety of reactor designs, from liquid-metal-cooled reactors through high-temperature gas-cooled reactors to molten salt reactors," which are among the six alternative designs cited by Ferguson. Of these one variation, the liquid metal fast breeder reactor (LMFBR), advanced further in terms of being built and tested: An experimental version (EBR-I) was built in Idaho in 1949, and the Enrico Fermi breeder reactor began construction in 1963 near Detroit. Rofer reports that both suffered partial meltdowns, the former in 1955, the latter in 1966, "both from blocked coolant channels." Yet, Rofer reports, "in about 1968, the resources of Shaw's Reactor Development and Testing Division were turned solely towards the development of a liquid metal fast breeder reactor, and all other projects were abandoned." This action, Rofer asserts, directed all of America's reactor research efforts toward a design which had already experienced serious problems and, at the same time, also deprived the U.S. of the benefits of more than forty years of research on other design alternatives to light water reactors.

Assessing the "Science Pipeline"

Having a sufficient workforce trained in science and engineering is an issue that has been addressed many times in this *Newsletter.* According to an article in the 20 July 2012 issue of *Science*, Yu Xie and Alexandra Killewald answer the question raised by their book, *Is American Science in Decline?*, with a flat "no." They argue that "leakage" from the "science pipeline" due to dropouts paints an inaccurate picture, because some dropouts never earn a college degree at all, a greater percentage of dropouts are in nonscience fields than in science and engineering, and there is also leakage *into* the pipeline from those switching *into* science fields. They also find that the percentage of students earning degrees in natural science or engineering exceeds the percentage of students intending to do so when they enter college. Responding to concern about a glut in the science pipeline, Xie and Killewald observe that the percentage of people with natural science or engineering degrees in science-related employment is between one half and two thirds, though this fraction decreases if those with social science degrees are included (as is the case with *Science and Engineering Indicators*).

More on Easter Island

The mystery of Easter Island has been discussed in this *Newsletter* since our Fall 1995 issue. Our most recent reference, in our Spring 2012 issue, was to a book by Terry Hunt and Carl Lipo, whose thesis was that building the statues there gave their society a focus that kept them from wastefully exploiting their limited resources. Tim Burgess, in the 16 February 2016 issue of the *San Diego Top News Examiner*, reported on a further article by Lipo, professor of anthropology at Binghamton University (NY), in the 16 February 2016 issue of *Antiquity*. In this article Lipo reported that he and his research team had analyzed 400 obsidian, triangular objects found on the surface, known as *mata'a*, and concluded that they were not used for weapons but rather for tattooing and farming, that they might have been good for cutting something, but not killing. Thus, Lipo concluded that the society on Easter Island did not experience its demise from internal warfare but rather from its first contact with the West, which is the thesis of his earlier book.

GM's Foray into Self-Driving Cars

Self-driving cars have become a frequent topic to this column, most recently in our Winter/Spring 2015 issue. The *Trenton Times* on 12 March 2016 reported that General Motors has acquired San Francisco-based Cruise Automation, Inc., whose technology will help it compete with Google in the race to develop self-driving cars. The first step is to develop the Super Cruise semi-autonomous system so that it can debut on the Cadillac CT6 sedan in 2017. Meanwhile, according to the *Trenton Times* of 1 March 2016, a Lexus SUV outfitted with Google's sensors and cameras hit the right side of a bus

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Fond Recollections of the Triangle Coalition

by Jane Konrad

The Pittsburgh Regional Center for Science Teachers (PRCST) was one of the first affiliates of Triangle Coalition for Science & Technology Education, later to become the Triangle Coalition for STEM Education. As PRCST Executive Director and Triangle Coalition representative, I presented at the Triangle Coalition's first national conference at Wingspread Conference Center, WI, under the direction of Triangle Coalition Executive Director John Fowler.

This was the "kick-off" for establishment of affiliates across the U.S. to promote the expansion of science and technology in current curricula. Annual conferences followed as affiliates grew and efforts were maximized. I attended and presented at these conferences as well.

Under Fowler's direction with support from Arthur Livermore (coming from AAAS), an Advisory Board was constructed to help plan policies and future directions. I served on this Board for many years, presenting ideas and programs, and integrating Triangle resources and programs.

At that time PRCST ran a relational database, LASER, Local Access to Science Education Resources, long before development of other databases. An accompanying newsletter was developed and eventually mailed to some 1400 science educators along with special workshops helping K-12 teachers learn to utilize available resources (including computers – then new in schools).

A strong effort was made by Triangle to integrate mathematics into the organization. But a formal agreement was never obtained. However, mathematics was always a part of the programs and resources – and served as a basis for the evolution from Science and Technology Education to STEM Education. Technology was always a significant part of all programs, and meeting with Bob Tinker encouraged PRCST to continue enhancement of the LASER Database – as he moved into curricular development. Publishing Directories and Guides was a primary effort of Triangle at that time. Utilization of community resources and volunteers emerged as a focus. A major national program was the Volunteer Project, developed by John Fowler with a grant from the Carnegie Corporation.

Five Pilot sites in the U.S. were selected to lead this project as each provided matching funds for each site. PRCST was a primary site addressing rural education in two school districts. This was a highly successful three-year project working to integrate local resources and volunteers. The program included meetings of teachers, administrators, scientists, and community representatives to ensure complete integration. Surveys provided basic information about the needs of educators and resources and interest available. Using the PRCST database, teachers could identify potential resources (speakers, materials) and arrange for their use. Training for both teachers and volunteers was held to ensure everyone understood the project and how to participate effectively. Paperwork (surveys, materials, organizational templates) was so successful that it was utilized at most pilot sites.

To expand this project throughout the U.S., Triangle arranged for PRCST to hold a three-day training workshop for all East Coast affiliates (Yakama Valley held the one for the West Coast). Lauren Williams came to Pittsburgh to help direct this effort. One school district site established by PRCST (Blackhawk, SD) was still operational in 2013! Later Williams and I worked at a Triangle Writing Team Conference in CO to rewrite and update the Volunteer Manual, which was never published.

During my years as Executive Director of the PRCST, the Triangle Coalition was always a supportive resource. Ours was a friendship that I will always treasure.

(*Editor's Note*: Although the PRCST is in the process of phasing out active programs and workshops, its *LASER* newsletter is still available online from its website.)

Clearinghouse Update

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while making a right turn from the right lane. The reason was that the lane's width required the Lexus to slide to the left to make the turn. At the time of the collision, the Lexus was going at 2 mph, while the bus in the lane to the left was going forward at 15 mph.

Molybdenum-99 Update

In following up the need to produce technetium-99m from the decay of molybdenum-99 for use in nuclear imaging procedures, this column reported in our Fall 2014 issue that the National Nuclear Security Administration had given Shine Medical Technologies a grant to produce molybdenum-99 from fission of a subcritical assembly of low-enriched uranium in accelerators. According to online *World Nuclear News* for 29 February 2016, the Nuclear Regulatory Commission has now authorized a construction permit to build this first-of-a-kind facility in Janesville, WI. It represents achievement of a goal of the National Nuclear Security Administration to produce molybdenum-99 and other medically-important isotopes without the need to use *highly*-enriched uranium.

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Using Cooking to Teach Chemistry, and Vice Versa

New York University Chemistry Professor Kent Kirshenbaum prefaced his talk on "A Soupçon of Science: Culinary Pedagogy" to the Physics Club of New York on 18 March 2016 with the observation that studies have shown that social media are more believable than science. He added that his own mother-in-law was skeptical about his efforts to bridge the gap between chemistry education and cooking, because "chemists want only to add chemicals to food" – in the vein of Saturday Night Live's "Shimmer," which doubled as a dessert topping and floor wax.

But having a product double as a cleaning agent and a food is really not that far-fetched, Kirshenbaum went on: many foods, including quinoa, contain saponins found in soap. He described his explorations on using saponins in cocktails – a boon to vegans not allowed to eat whipped cream. He also reported being able to bake meringues from a mixture of chickpea brine and sugar (another boon to vegans not allowed to eat egg whites) and passed them around for the audience to sample. To Kirshenbaum, these examples illustrated what he saw as a trend toward more plant-based foods. This trend would offset the high energy and environmental cost of animal food (20% of fossil fuel use and a third of greenhouse gas emissions result from food production); it would also be a reason for everyone to learn chemistry.

To this end Kirshenbaum has founded the Experimental Cuisine Collective (experimentalcuisine.org), which has monthly meetings and 2000 members. Their mission is to show that food is made of atoms and that smell and taste, like food itself, are chemically based.

"How can scientists advance cuisine?" and "How can chefs advance science?" he asked. In response to the first question, scientists, in investigating the chemical content of foods, unearth risks, like a slew of carcinogens in smoke which naturally occur from cooking meat over a fire. Liquid nitrogen, centrifuges, and ultrasound, equipment normally associate with science labs, are now showing up on TV food shows, he added. And cooking at precise temperatures and times have enabled the production of new textures (Kirshenbaum used eggs as an example).

In response to Kirshenbaum's second question, chefs can advance science education by cooking with young children, with an explanation of what is happening providing a chemistry lesson and the message that not all chemicals are bad for you.

Kirshenbaum also cited the protein, miraculin – a pH-dependent allosteric agonist/antagonist of a sweet taste receptor, which makes sour things taste sweet. In doing this, it can satisfy people's craving for sweets without overloading them with sugar.

He also stated that he would like to create new partnerships with chemistry teachers in schools to outreach beyond the Experimental Cuisine Collective. At this point Disan Davis, chemistry teacher at Hunter College High School, with whom Kirschenbaum has established such a partnership, described how she has included food chemistry in her teaching the past three years. One approach is to vary ingredients in a recipe to see the effect on yield, quality, and flavor (her examples included ricotta cheese, sauerkraut, bread, pretzels, and hard candy). Another is the separation of matter – extracting lipids and pigments (from, say, an avocado). Many applications of acids, bases, and solutions abound in cooking.

Davis also described the intermolecular forces professional development using food-related topics she runs at Rockefeller University. Kirshenbaum concluded by stressing that, for health reasons, it is important for chefs and scientists to work together.