TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION NEWSLETTER

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Disruptive Technology — Then, Now, and Next

by John D. White

How we got here and how fast . . .

Several technologies arose long ago in single cultures, only to fade and re-emerge later in other locations. For example, Roman ornamental glass-making was abandoned in 5th-century Britain, but revived in 8th-century Venice, and arose again in 13th-century Britain for windows of Gothic cathedrals. Other technologies, such as firing ceramics, smelting metals, herding domesticated animals, and sowing crops, both persisted and spread to distant locations. Recent discoveries hint that early humans in North America brought or invented stone weapons enabling the extermination of most large mammals. Despite their major impacts, many other achievements may have occurred slowly as refinements to processes.

In medieval Europe generations passed without changes of technology. In a typical life, one might see a single layer of stone added to the new cathedral's walls, but prevailing chisel designs and lifting techniques dated from Egypt's pyramids. Two inventions—probably imported from the east—transformed the Middle Ages and fomented the Enlightenment. One, the stirrup, enabled a toppled knight to re-mount his horse alone. A corps of armored cavalry then empowered the lord of a manor to protect and dominate a far larger area, laying the foundation of the nation-state. The other invention, the horse collar, enabled producers and merchants in a single day to cover twice the distance of ox-carts, thus doubling the radius of markets. Horse-drawn carriages promoted comfortable travel over greater distances, thus encouraging pilgrimages, foreign study, and even tourism, Great as these changes were, their slow acceptance comprised gradual evolution rather than the dramatic shift we call *disruptive.* Since the Renaissance, however, both the variety and speed of inventions have accelerated so much that in the current century, merely tracking the changes, to say nothing of understanding and adapting, has overwhelmed most observers.

Disruptive and even destructive . . .

Steamboats and digital cameras were not just evolutionary refinements of existing technologies, but comprised such impressive changes they have come to be called *disruptive technologies.* The concept has existed at least since the 1750 Industrial Revolution in Great Britain, but this term itself dates to Clayton M. Christensen's 1995 book *The Innovator's Dilemma*. Before 1950 changeovers from one dominant technology to its replacement occurred over a span of 50 to 100 years. In recent decades the rate of change has itself accelerated, but many of the developments we see are linear improvements rather than disruptive revolutions. The latter have broad impact, quickly moving 90° or even more from the *status quo*.

The steam engine in the 1700s propelled the Industrial Revolution in a startling way: mills for grain, lumber, and textiles for the first time in history could be placed near the ideal work site, and not just near the source of water or wind power. Soon the steam engine itself began to move the wagon or ship laden with finished goods, raw materials, and passengers. In one ironic story of destructive technology, the 1793 Middlesex Canal in Massachusetts prospered half a century, drawing a handsome profit from carrying materials to build the nearby Boston & Lowell railroad. The latter used the original route surveyed by the canal builders and with its faster transport, forced the shutdown of the canal in 1851.

(continued on page 10)

An EDITORIAL: Are objectors to the science "establishment" really objecting to the rules of science?

Martin Enserink reported in the 12 March 2010 issue of *Science* that after publication of two papers denying that HIV causes AIDS, publisher Elsevier threatened Bruce Charlton with non-renewal of his contract to edit *Medical Hypotheses* unless he instituted peer review, a practice that many feel would inhibit publication of wacky ideas that could eventually prove to be important. Opposers of the papers are concerned about the effect of AIDS-denying papers on medical treatment in South Africa, where AIDS-denialism is prevalent. One of the papers' author complains about "'censorship' imposed by the 'AIDS establishment.'"

Complaints about the "AIDS establishment" are reminiscent of those by climate change deniers against the "climate change establishment." One climate change denier, the late author Michael Crichton, in a 17 January 2003 lecture at Caltech, used the word *consensus* to protest the exclusion of opposing ideas by what might be termed an "establishment," and he applied this to Frank Drake's equation for the probability of finding extraterrestrial intelligent life, the equation used by Carl Sagan and colleagues in predicting "nuclear winter," the initially-believed causes of puerperal fever and pellagra, the consensus that opposed Alfred Wegener's theory of continental drift, what he felt to be the EPA's premature classification of secondhand smoke as a carcinogen along with what he felt is misplaced reliance on computer modeling in predicting climate change. Advocates of intelligent design undoubtedly consider the community of biologists to be an "establishment."

Crichton argued that "Consensus is invoked only in situations where the science is not solid enough." But in *The Structure of Scientific Revolutions* Thomas Kuhn portrays science is being done in accordance with an established paradigm, which has gained acceptance by the community of scientists by virtue of its ability to account for the data that have so far been observed. Yes, the prevailing paradigm in a scientific field has been, in effect, accepted by a "consensus" of those practicing in it, but that it is because that paradigm has been successful in accounting for what has been learned at that time through experimental measurement. The theories embodied in a paradigm must explain the observed data, and once they are found not to, they must be modified or discarded – as, for example, Newtonian physics gave way to the theories of relativity and quantum mechanics. Eventually, Alfred Wegener had his time of acceptance, when prevailing paradigms in geology could not account for the observations Wegener cited.

Thus, those who object to an "establishment" or a "consensus" in an area of science are really objecting to the paradigm by which that area of science has accepted as the paradigm for doing its work. It is up to objectors to bring to the table data that cannot be explained by theories embodied in the paradigm. Advocates of intelligent design have thus far not been able to come up with data that cannot be accounted for by evolution, and they have been equally unsuccessful in coming up with a competing theory that can be tested in accordance with the procedures of science.

- John L. Roeder

The TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION, INC., was founded at The New Lincoln School on 11 March 1982 by 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 194 Washington Road, Princeton, NJ 08540-6447 or via e-mail at <JLRoeder@aol.com>. The Clearinghouse is sponsored by the Association of Teachers in Independent Schools, Inc., and is affiliated with the Triangle Coalition for Science and Technology Education.

NJAAPT Spring Meeting highlights Physics in our Lives

The theme of the spring meeting of the New Jersey Section of the American Association of Physics Teachers on 23-24 March 2012 at Princeton University might be called "Physics in Our Lives." Four speakers addressing the meeting spoke on energy issues, and a fifth described the elevation of the roadway of a bridge.

The first speaker was electrical contractor Jim Krutzler, who described his experiences with solar energy in his talk on "My Journey with the Sun." This journey began when Krutzler learned that a 70% rebate from the Bureau of Public Utilities (BPU) and the additional profit from selling Solar Renewable Energy Certificates (SRECs) would make installation of an array of photovoltaic solar panels on his roof affordable. He showed pictures of his 28 panels, which have a generating capacity of 6000 watts, and pointed out that the photovoltaic cells in those panels produce DC electricity from incoming sunlight with 17-18% efficiency. This DC electricity in turn is converted to AC with 96% efficiency by an inverter and transmitted to the grid. Krutzler had hoped that his solar panels would keep the lights on in case of a power failure, but he learned that when the grid goes down, the inverter shuts down, too. The alternative of being off the grid would require 20 car batteries for DC storage, and they would need to be replaced every five years.

Krutzler added that the solar panels degrade about half a percent per year, are warranted to last 25 years and could last up to 40 years. The inverters are warranted for six years, with warranty extensions for 10-15 years available. When he generates more electricity than he uses, he pays Jersey Central Power and Light only a $2.20 service charge instead of the $225 he used to pay each month. Of the $86,000 cost of his system, $55,000 was paid by the BPU, leaving only $31,000 to come from his pocket. In the first five years of having his system he has more than made this back with $33,000 income from the sale of SRECs (to utilities who are mandated by law to have a certain percentage of renewable electricity sources in their portfolio), in addition to the $2700 he has saved by having to pay only the $2.20 monthly service charge.

In addition to generating solar electricity, Krutzler also generates solar heat. Here he described two options – flat plate and evacuated tube. The former consists of 6' x 3' mounted collectors, but they are effective only between April and September and are more useful for heating swimming pools. In evacuated tube solar collectors a vacuum between two nested coaxial tubes insulates the liquid (typically propylene glycol) inside the inner tube (to keep it at 150^{o}C). Krutzler has twenty such collectors, which provide his space heating – but he added that he needs to shut this system down in summer, until he gets an outdoor swimming pool.

The second speaker was Alfonso Gandica, founder of the Information and Systems Science Department at Stockton College of New Jersey who later joined Atlantic City Electric until his retirement in 1998. Since then he has established his own consulting firm and continues to teach as an adjunct at Stockton. Gandica's talk on "Renewable Energy Sources Options" drew from two sources: the Energy Information Administration, which he called "the world's best source of information about energy," and *Reinventing Fire: Bold Business Solutions for the New Energy Era*, by Amory Lovins (Chelsea Green, White River Junction, VT, 2011).

Because the actual maximum conversion efficiency from thermal to electrical energy is 31%, Gandica pointed out that most energy for generating electricity ends up as waste heat, except for combined cycle operations, which run at 50% efficiency. Coal, which is the leading fuel for generating electricity, is very abundant, cheap, and dirty, Gandica said. We have counteracted it with the Clean Air Act, and we can do more with carbon capture and sequestration (CCS), he added.

Because of the political instability of many oil-producing regions of the world, Gandica continued by observing the wisdom of importing less oil and noting that our percentage of imported oil has decreased since 2006, though our production of natural gas has increased. The best way to reduce dependence on oil, Gandica said, was higher CAFE standards for gasoline mileage of vehicles. He displayed a visual from *Reinventing Fire* showing that the cost of oil dependence to the U.S. economy from wealth transfer, dislocation losses, and loss of potential gross domestic product has increased to $400 billion per year. Another visual from *Reinventing Fire* showed how Lovins, in the words of the dust jacket to his book, "maps pathways and competitive strategies for a 158% bigger 2050 U.S. economy that needs no oil, no coal, no nuclear energy, one-third less natural gas, . . . no new inventions . . . no new federal taxes, subsidies, mandates, or laws." (You can see these visuals and read the words on the dust jacket at the Amazon website.)

Gandica went on to tell us that his favorite renewable energy resource is biomass. Denmark, he said, burns 80% of its solid municipal waste to produce electricity

(continued on page 4)

NJAAPT Spring Meeting

(continued from page 3)

and heat, while only 13% is so treated in the U.S., including that at the Camden County Energy Recovery Facility. (Waste that is hazardous to health cannot be accepted, he added, and metals are pulled from the waste stream before it is burned.) Waste-to-Energy (WTE) plants generate 2600 megawatts of electricity, he said, and, with their environmental controls, they release fewer air pollutants of all kinds than comparable plants energized by fossil fuels.

Dennis Stabile, Program Manager for the Bayonne Bridge Navigational Clearance Program of the Tunnels, Bridges and Terminals Department of the Port Authority of New York and New Jersey, next spoke about the "Bayonne Bridge Navigational Clearance Program." Stabile explained that the expansion of the Panama Canal due in 2014 will triple the capacity of ships passing through it. This in turn will make the Bayonne Bridge (connecting Bayonne, NJ, with Staten Island, NY) a constraint to the new "post-Panamax" ships wanting to reach north Jersey ports. The Bayonne Bridge was built in 1931, carries 20,000 vehicles per day (a small amount compared to 300,000 per day across the George Washington Bridge), but its roadway provides only 151 feet of clearance above the water below, and 200 feet are needed for the post-Panamax vessels.

According to Stabile, three alternatives were considered:
1) modifying the bridge, by a) raising the roadway, b) jacking up the arch, or c) lifting the entire bridge.
2) replacing the bridge, with a a) new bridge or b) a tunnel.
3) nonbridge options: a) ferry service, b) alternate site improvements, or c) a lock system.

The choice was to modify the bridge by raising the roadway – and to do it without shutting the bridge down (except for some night closings). The 151' clearance will be raised to 215', and the width of the 6' walkway (cantilevered outside the arch) will be doubled. Four 12' lanes will replace the current four 10' lanes, and a median will be added. Extending the light rail system that presently ends at Bayonne would also be possible. The approach grade will be 4.85% (5% is the desired maximum) and the bridge will still be accessible from all present approaches. New approaches and towers will be constructed, replacing one side while the other accommodates one lane of traffic in each direction, then using the first half of the new bridge to maintain one lane of traffic in each direction as the remaining half of the lower roadway is demolished in time for the 2014 Canal improvements, with the fully-operational new bridge slated for 2016. Stabile added that accelerating the project is actually reducing costs. Information about and pictures of the project are available at <www.panynj.gov/bridges-tunnels/bayonne-bridge.html>.

Craig Arnold, a physicist in Princeton University's Department of Mechanical and Aerospace Engineering, next spoke about "The Mechanics of Electrochemical Energy Storage." Batteries, Arnold began, are important, because we don't necessarily generate electrical energy where and when we need it. But one single device is not a feasible solution to all our battery needs, and we must make tradeoffs to enable different devices to meet different specific needs.

Arnold reviewed the history of electricity, beginning with the Ancient Greeks, who discovered that static electricity could be generated by rubbing insulators against each other. Then in 1745 Musschenbroek and Cunaeus discovered the Leyden jar as a way to store electrical energy. Cavendish used these jars to discover but not publish things later discovered and published by Ohm, Faraday, Maxwell, and Coulomb. Franklin showed that lightning is the same kind of energy stored in Leyden jars. Galvani hypothesized that his observed twitch of frog legs came from "bioelectricity," but Volta showed with his pile of zinc and silver that Galvani's electricity came from metals, not from the frog – from electrochemical redox reactions. The battery is a compact device to convert chemical to electrical energy – ditto for fuel cells. Its technology did not change much, until the 1990s, Arnold said, when the need for nickel-cadmium, lithium-ion, and lithium-polymer batteries developed.

Though batteries are energy storage devices, Arnold noted that we usually speak of them in terms of energy discharge. He also spoke of the Ragone relation that the specific power and specific energy of batteries are inversely related. Moreover, batteries are mechanical and thermal as well as electrical devices, Arnold said. Thus, combined mechanical events act to stress batteries, and these stresses in turn affect battery performance. By studying the mechanics of electrochemical systems, Arnold pointed out, we can understand limitations and develop improvements. Lithium, he said, may not ultimately be the basis for the best future battery – it's expensive and not found in the most friendly places in the world. Toyota has indicated that the next generation battery will be based on magnesium but has not been forthcoming with details. Arnold added that the lead-acid batteries found in most of today's automobiles are very easy

(continued on page 6)

USDOE and AAAS launch Energy Literacy Initiative

Are you energy literate? As a result of a fall 2010 workshop sponsored by the US Department of Energy and the American Association for the Advancement of Science, *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education* has been developed. Designed to help people "make more informed decisions on ways to save money by saving energy" and to provide a basis for educators to design curricula, this document can be accessed online at <www.globalchange.gov/resources/educators>. It "identifies seven Essential Principles and a set of Fundamental Concepts to support each principle . . . drawn, in part, from existing education standards and benchmarks" and presents six characteristics of an energy-literate person and the benefits of energy literacy. "An energy-literate person (1) can trace energy flows and think in terms of energy systems, (2) knows how much energy he or she uses, for what, and where the energy comes from, (3) can assess the credibility of information about energy, (4) can communicate about energy and energy use in meaningful ways, (5) is able to make informed energy and energy use decisions based on an understanding of impacts and consequences, and (6) continues to learn about energy throughout his or her life. The Essential Principles and Fundamental Concepts are as follows:

1. Energy is a physical quantity that follows precise natural laws.

1.1 Energy is a quantity that is transformed from system to system.

1.2 The energy of a system or object that results in its temperature is called thermal energy.

1.3 Energy is neither created nor destroyed.

1.4 Energy available to do useful work decreases as it is transferred from system to system.

1.5 Energy comes in different forms and can be divided into categories.

1.6 Chemical and nuclear reactions involve transfer and transformation of energy.

1.7 Many different units are used to quantify energy.

1.8 Power is a measure of energy transfer rate.

2. Physical processes on Earth are the result of energy flow through Earth system.

2.1 Earth is constantly changing as energy flows through the system.

2.2 Sunlight, gravitational potential, decay of radioactive isotopes, and rotation of the Eath are the major sources of energy driving physical processes on Earth.

2.3 Earth's weather and climate are mostly driven by energy from the Sun.

2.4 Water plays a major role in the storage and transfer of energy in the Earth system.

2.5 Movement of matter between reservoirs is driven by Earth's internal and external sources of energy.

2.6 Greenhouse gases affect energy flow through the Earth system.

2.7 The effects of changes in Earth's energy system are often not immediately apparent.

3. Biological processes depend on energy flow through Earth system.

3.1 The Sun is the major source of energy for organisms and the ecosystems of which they are a part.

3.2 Food is a biofuel used by organisms to acquire energy for internal living processes.

3.3 Energy available to do useful work decreases as it is transferred from organism to organism.

3.4 Energy flows through food webs in one direction from producers to consumers and decomposers.

3.5 Ecosystems are affected by changes in the availability of energy and matter.

3.6 Humans are part of Earth's ecosystem and influence energy flow through these systems.

4. Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.

4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors.

4.2 Human use of energy is subject to limits and constraints.

4.3 Fossil and biofuels are organic matter that contains energy captured from sunlight.

4.4 Humans transport energy from place to place.

4.5 Humans generate electricity in multiple ways.

4.6 Humans intentionally store energy for later use in a number of ways.

4.7 Different sources of energy and the different ways energy can be transformed, transported, and stored each have different benefits and drawbacks.

5. Energy decisions are influenced by economic, political, environmental, and social factors.

5.1 Decisions concerning the use of energy resources are made at many levels.

5.2 Energy infrastructure has inertia.

5.3 Energy decisions can be made using a systems-based approach.

5.4 Energy decisions are influenced by economic factors.

(continued on page 6)

NJAAPT Spring Meeting

(continued from page 4)

to recycle, much more so than lithium batteries, because of the complicated ways lithium is bound in them.

The last speaker, speaking on "Nuclear Power Looking Forward (After Fukushima)," was JoEllen Burnz Muntz of Exelon Nuclear. What disabled the Daiichi Fukushima reactors, Muntz said, was the tsunami, not the earthquake. The reactors have now been stabilized, she added, and the preparation for decommissioning them with an overlaid sarcophagus is now underway. The severe radiation releases in the first week have had little public health impact, due to timely evacuation and monitoring. Although the U.S. has a safer reactor design in terms of water tightness, she went on, the U.S. has decided to strengthen its backup, and do it in a different place.

Muntz pointed out five areas of regulatory response in which the need for improvement was recognized:

1) Improve ability to maintain safety with extended loss of power.
2) Add a second system to monitor spent fuel storage.
3) Ensure reliable containment venting.
4) Evaluate protection against extreme events.
5) Enhance emergency planning.

In addition to emergency response, two other important layers of safety are mitigation and protection.

Nuclear energy presently provides 20% of U.S. electricity, Muntz observed, and between four to eight new reactors are expected to be in operation by 2020. The AP1000 design has been approved by the Nuclear Regulatory Commission, and three new advanced reactor designs are under review. Requests for eighteen Combined Construction and Operating Licenses have been received, with six subsequently suspended or withdrawn. And there is a growing interest in small modular reactors, she added. But, at the same time, fracking has caused natural gas to become a more plentiful, inexpensive, and attractive energy source.

Energy Literacy Initiative

(continued from page 5)

5.5 Energy decisions are influenced by political factors.

5.6 Energy decisions are influenced by environmental factors.

5.7 Energy decisions are influenced by social factors.

6. The amount of energy used by human society depends on many factors.

6.1 Conservation of energy has two very different meanings.

6.2 One way to manage energy resources is through conservation.

6.3 Human demand for energy is increasing.

6.4 Earth has limited energy resources.

6.5 Social and technological innovation affects the amount of energy used by human society.

6.6 Behavior and design affect the amount of energy used by human society.

6.7 Products and services carry with them embedded energy.

6.8 Amount of energy used can be calculated or monitored.

7. The quality of life of individuals and societies is affected by energy choices.

7.1 Economic security is impacted by energy choices.

7.2 National security is impacted by energy choices.

7.3 Environmental quality is impacted by energy choices.

7.4 Increasing demand for and limited supplies of fossil fuels affects quality of life.

7.5 Access to energy resources affects quality of life.

7.6 Some populations are more vulnerable to impacts of energy choices than others.

The meeting concluded with a presentation of "Dissimulating Demos" by Jim Olsen and Omelian Stryzek of Princeton University's Physics Department, so titled because they showed how they presented the demonstrations to Princeton's students, asking them to signal with their clickers what they predicted would happen.

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

25 July – 1 August 2012, American Association of Physics Teachers: "Physics: the Experimental Core," Philadelphia. Visit <http://www.aapt.org>.

13-14 September 2012, World Nuclear Association 37th Annual Symposium, Central Hall Westminster, London: "Back to Business." Visit <http://www.wna-symposium.org>.

1-2 October 2012, Triangle Coalition 12th annual Conference on STEM Education: "World-Class STEM Education in America: Building on the Global Perspective," Arlington, VA. Visit <www.trianglecoalition.org/conference>.

Wagner addresses creating innovators

On 17 April 2012 Tony Wagner's new book, *Creating Innovators: The Making of Young People Who Will Change the World*, was published. Two days later Wagner spoke at The Peddie School in Hightstown, NJ, under the auspices of Princeton Common Ground, a consortium of Parents Associations of independent schools in the Princeton area.

What is the "problem/crisis" in American education, Wagner began by asking. His answer to his rhetorical question was twofold: 1) In the new global economy all students need new skills – for work, continuous learning, and citizenship; 2) Education needs to be reinvented, not just reformed. When information abounds, as it does today, Wagner observed, the *world doesn't care what students know but what they can do with what they know*. He added that *The World is Flat* is the most important book he has read in a decade.

Wagner went on to list what, in addition to "Habits of the Heart," he termed Seven Survival Skills for Careers, College, and Citizenship:

1. Critical thinking and problem solving
2. Collaboration across networks and leading by influence (Here he lamented that education is one of the most isolated professions.)
3. Agility and adaptability
4. Initiative and entrepreneurialism
5. Effective oral and written communication (Here he observed that communication also requires thinking.)
6. Accessing and analyzing information
7. Curiosity and imagination

He next alluded to his earlier book, *The Global Achievement Gap* (2008), which describes the difference between what schools teach and test and what all students need. Our economy is fueled by consumer spending, he said, financed by debt – people spending money they don't have on what they may not need and endangering the planet.

Turning to his current book, Wagner then pointed up the answer to all the problems he had described: innovation. For this book, Wagner said he interviewed well-known innovators, many of whom had dropped out of college, also their parents and the few teachers and mentors they could cite. He also noted that these teachers and mentors were outliers, using unorthodox methods.

He closed the formal part of his talk with a series of contrasts between the culture of schooling and the culture of innovation:

Culture of schooling	***Culture of innovation***
Individual achievement	Collaboration
Specialization	Problem-based interdisciplinary learning
Risk avoidance	Trial and error (Olin College of Engineering refers to this process as "iteration")
Consuming	Creating
Extrinsic motivation	Intrinsic motivation

To emphasize the importance of trial and error, Wagner urged students to "fail early and fail often." He also encouraged them to experience play, passion, and purpose (which leads to perseverance). He also noted that students, as "digital natives," are accustomed to instant gratification and always being connected; use the web for social, educational, and expressive reasons; connect, create, and multitask, except in school; respect peers more than authority; and want to make a difference more than money. He urged society to shift from consumption-driven, information-based learning to creation-driven, transformation-based learning.

In the question-and-answer period following, Wagner observed that there is little innovation at the college level, particularly at large research-driven institutions. Independent schools are no longer a gateway to selective colleges, and selective colleges are no longer a gateway to getting a job, except at the graduate level. He went on to note that many colleges no longer require tests for admission and cited Tufts' invitation to students to submit YouTube videos.

Montessori Schools, he said, satisfy all his criteria, but they require confidence in children's ability to develop

(continued on page 8)

Science Ed Orgs Respond to Draft of NGSS

Our Fall 2010 and 2011 issues have reported on the *Framework For K-12 Science Education* developed by the National Research Council, as the basis of the Next Generation Science Standards (NGSS), which have now been released in draft form by Achieve, Inc. For each general topic, the draft lists performance expectations, followed by science and engineering practices, disciplinary core ideas, crosscutting concepts underlying them, and connection to other disciplinary core ideas and to Common Core State Standards. The kindergarten and grade 1 curricula each focus on three topics, and grades 2 -5 focus on four, as follows:

K	2	4
Organisms and Their Environments Structure and Properties of Matter Weather	Earth's Changing Surface Structure, Properties, and Interactions of Matter Interdependence of Organisms and their Surroundings Pushes and Pulls	Life Cycles and Traits Processes that Shape the Earth Energy Waves
1	3	5
Structure and Function Light and Sound Patterns and Cycles	Weather, Climate, and Impacts Environmental Impacts on Organisms Structure, Function, and Stimuli Interactions of Forces	Matter and Energy in Ecosystems Earth Systems and Their Interactions Stars and the Solar System

(continued on page 9)

Clearinghouse Update

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

More on Easter Island

The Clearinghouse Update of our Fall 2006 issue cited an article by Terry Hunt in the Sep-Oct 06 issue of *American Scientist* giving an interpretation of what happened on Easter Island different from that of Jared Diamond in *Collapse* (reviewed in our Spring 2006 issue). Hunt has apparently teamed up with Carl Lipo to develop this interpretation of events on Easter Island into a book, *The Statues that Walked: Unraveling the Mystery of Easter Island* (Free Press (Simon & Schuster), New York, 2011), ISBN 9781439150313. According to a review in the 27 January 2012 issue of *Science* by Robin Torrence, Hunt and Lipo's interpretation is that, while statues elsewhere in Polynesia signified competition, on Easter Island they provided focus to a society faced with limited resources, that they might have wasted had they not kept busy building the statues (which they could "walk" vertically on a network of newly-discovered roads). Disintegration of Easter Island's civilization came when Western contact diverted the islanders from this focus.

Bartlett Article Republished

The lead story of our Winter 2012 issue, Al Bartlett's article on "The Meaning of Sustainability," has been republished – in the May 2012 issue of *Mother Pelican*, an online "Journal of Solidarity and Sustainability." The URL for the homepage, from which all issues of *Mother Pelican* can be accessed, is <http://www.pelicanweb.org>.

Wagner

(continued from page 7)

their own passions; China, in turn, is establishing 500 of them. He applauded service learning requirements and cited the requirement at High Tech High (San Diego) for groups of ninth graders to write and present a plan to develop their own business or service company.

To help children find their own passions, Wagner recommended offering them a buffet of experiences but not scheduling every moment of their lives. Once a passion is found, he added, it is important to sustain it. One possibility is a "gap" year between high school and college – Wagner said that research showed that students taking a "gap" year outperformed students who did not.

(continued on page 30)

Science Ed Orgs Respond to Draft of NGSS

(continued from page 8)

For middle school and high school a series of topics is prescribed for each of the four basic disciplinary categories, as follows:

Middle School	High School
Life Sciences	Life Sciences
Structure, Function, and Information Processing Growth, Development, and Reproduction of Organisms Matter and Energy in Organisms and Ecosystems Interdependent Relationships in Ecosystems Natural Selection and Adaptations	Structure, Function, and Information Processing Matter and Energy in Organisms and Ecosystems Interdependent Relationships in Ecosystems Inheritance and Variation of Traits Natural Selection and Evolution
Earth and Space Sciences	Earth and Space Sciences
Space Systems History of Earth Earth's Interior Processes Earth's Surface Processes Weather and climate Human Impacts	Space Systems History of Earth Earth's Systems Climate Change Human sustainability
Physical Sciences	Physical Sciences
Structure and Properties of Matter Chemical Reactions Forces and Motion Interactions of Forces Energy Waves and Electromagnetic Radiation	Structure and Properties of Matter Chemical Reactions Nuclear Processes Forces and Motion Interactions of Forces Energy Forces and Energy Waves Electromagnetic Radiation
Engineering, Technology, and Applications	Engineering, Technology, and Applications
Engineering Design Links Among Engineering, Technology, Science and Society	Engineering Design Links Among Engineering, Technology, Science and Society

After meeting with the American Physical Society, the American Chemical Society, the American Institute of Physics, the American Association of Engineering Education, and the US Department of Energy, the American Association of Physics Teachers criticized the draft NGSS for not extending "the intellectual and pedagogical structure of the *Framework* to the formulation of the Science Performance Expectations." They felt that for each topic "there should be several performance expectations, each involving one or more science and engineering practices," rather than the present random attachment of one science and engineering practice to a subtopic to generate each performance expectation. There was also surprise at "the lack of connection with previous articulations of science education standards," like the AAAS *Benchmarks for Science Literacy*.

The National Science Teachers Association (NSTA) voiced many of the same criticisms. NSTA recommended that each set of performance expectations should include an explanation of why they are grouped together and that "every core idea should have at least two performance expectations that probe it." Also seeking continuity with the previous *Benchmarks* and *Standards*, NSTA says that the grade level for learning concepts specified in these documents should not be different in the NGSS without justification by published research.

Disruptive Technology

(continued from page 1)

Another revolution shifted the nation from lighting based on beeswax, whale oil, and kerosene to electric arc and filament lights. Within two generations cheap, all-night illumination replaced many a worker's sleeping pattern with "swing" or "graveyard," the newly-created new factory shifts.

Entertainment expanded into evening hours with well-lit stage shows and then movies, both encouraged by safer travel after dark. Electric lights simply re-invented the half-day after sundown. Merely *linear* change rarely created new markets or societal structures, but altered existing ones over time. In contrast, disruptive change creates new markets and re-organizes activities while it quickly destroys older ones. Henry Ford's introduction of cheap automobiles not only ended the buggy whip industry and reduced hay production, but generated vast rubber, steel, and glass production, and magnified petroleum refining to supply retail gasoline stations, dwarfing petroleum's role as lighting fuel. Such interconnected growth inspired Congress to pass the Federal Highway Act of 1916 which itself led to construction of a concrete and asphalt roadways network with roadside motels, diners, amusement parks, outdoor signs, and drive-in movies. In the first two decades of the 1900s, cars and public transit expansion had turned the US and Canada into the Horseless Generation.

A quick survey of technology history shows that offering the first, even the best, of a new product or service may not secure long-term financial success. John Fitch's 1787 steamboat and patent were the first in the United States, despite opposition by James Rumsey with his similar design. However, Robert Fulton with his *Clermont* later won the political, legal, and financial victories, plus recognition by history books. Elias Howe deserved the most credit for the sewing machine, but Isaac Singer still took over the industry and marketed it around the world. By the 1890s Edison's preference of direct current had lost the market battle to the alternating current promoted by Westinghouse and Tesla. Edwin Armstrong invented FM radio but Sarnoff's RCA pressured the FCC to let the later rival to take control of that broadcast medium. SONY's Beta video recorder technology arrived first and won praise for superior performance, but VHS swept Beta into the dustbin.

Soon after its founding in 1889 and for the next century, Eastman Kodak controlled as much as 90% of the photography industry from Brownie home cameras to sophisticated industrial processes. With an ironic consequence, Kodak in 1987 introduced consumer-level digital photography – only to go bankrupt in January 2012 because of that invention while its competitors thrived. My own household enjoys our three digital Kodak models and had hoped for better days for the Rochester giant, but the next month after bankruptcy, Kodak announced it would stop making the digital cameras it had invented.

Revolution followed by evolution

The disruptive phase of rapid changeover in lighting from flame to tungsten filament produced extensive side-effects: cutting whole forests for utility poles, toxic chemicals spread by wood-preservation plants, manmade canyons for open-pit copper mining not far from new mountains of spent ore, and smelter pollution harming huge areas. The benefits came from new industries and jobs to supply wire and fixtures, light bulbs, and then cook stoves, radios, refrigerators, and motors. As the lighting industry matured, the changes became more gradual and incremental. Incandescent lamps competed with fluorescent tubes, in turn sharing the market with other types – mercury vapor, sodium vapor, spiral CFLs, and now LCDs ranging from pocket flashlights to brake lights and overhead traffic lights. Even newer OLEDs enjoy a promising future, according to developers displacing older LEDs. The disruptive phases in transport arose when steam, gasoline, or diesel-powered vehicles replaced muscle and wind power from submarines to space vehicles.

How "disruption" differs from other changes:

Here are a few terms from the emerging vocabulary that describes types of innovation:

- **Sustaining:** The change is merely additive with minimal effect on existing markets **(**new colors in the box of Crayolas, additional flavors in Lifesaver packages)

(continued on page 11)

Disruptive Technology

(continued from page 10)

- **Evolutionary:** This means incremental refinements improving a product in ways that customers would want and expect (radial tires entering the market accustomed to bias-ply, lithium-ion car batteries instead of lead -acid, electric typewriters and as an option instead of manual models)

- **Revolutionary:** Major, even rapid change not anticipated by the market but exerting little change on current markets (includes most fads, and many consumer products such as smartphones, iPads, which leave intact current use of older types of telephones and computers).

- **Disruptive:** Quoting from a Wikipedia article: "An innovation that creates a new market by applying a different set of values, which ultimately (and unexpectedly) overtakes an existing market. (e.g., the lower priced Ford Model T)." [http://en.wikipedia.org/wiki/Disruptive_technology] The following quotation suggests the impacts likely to ensue from such innovation:

> A disruptive technology is one that, when introduced, either radically transforms markets, creates wholly new markets or destroys existing markets for other technologies. For an investor, disruptive technologies represent both opportunities and threats. A disruptive technology will be an opportunity for at least those who bring it to market. It may also boost related markets. On the other hand change is usually bad for some — especially the dominant suppliers to the market being disrupted. [http://moneyterms.co.uk/disruptive-technology/]

Evolutionary change may, like the proverbial *mills of the gods*, grind slowly, but exceedingly fine. The lucky drayman was able to finish a career driving his horse to the rail station to haul packages, but in time he and his beast retired completely. Automobiles, airplanes, and buses, replaced a vast network of rail passenger lines. The vacuum tube radio or television yielded to the semiconductor. The few remaining CRTs soon will depart for recyclers, having been replaced by LCDs, LEDs, and plasma screens.

Looking for nine of the next disruptions:

At first, one should acknowledge the risks of predicting specific changes for onrushing decades. Fuel cells and fusion energy have been favorite "just around the corner" topics of futurists so long they enough make everyone reluctant to forecast technology changes. *Popular Science* magazine often features the educated guesses of experts from long ago, and they are enough to provoke both a sense of humility and humor. Nonetheless, here are some general areas of development that appear likely to transform the next generation's world.

1. **Synthetic biology**: This field demands STEM cooperation for perhaps the most dramatic progress in history: Diverse approaches include producing cheap new biofuels, curing diseases, correcting genetic disorders, enhancing agricultural production, and pollution abatement. Experiments well under way now will surely revolutionize medical treatments by manipulating and combining proteins or other materials into unrelated organisms. Even bacteria and viruses serve as donors for much more complex plants and animals. Topics will certainly diversify and appear more often in the pages of this and other periodicals when the activities gain funding and participants. As typical antibiotics lose effectiveness to resistant strains of pathogens, synthetic biology grows more important in providing alternate therapies.

2. **Graphene** and other materials science breakthroughs: After World War II, cheap but superior quartz crystal technology replaced centuries-old spring movements to transform the luxury wristwatch industry. In a similar upheaval, germanium transistors, gallium arsenide, and integrated circuits became familiar to people raised on crystal radios and vacuum-tube audio devices. A more familiar material, carbon, took on a new aura. Very expensive, high-performance applications replaced other composites in fishing rods, sailboat masts, and hypersonic aircraft. Exotic forms of ubiquitous carbon such as fullerene ("buckyballs") soon drew attention. One of the latest, single-atom-thick graphene, may offer promise greater than that of the doped semiconductor. This flexible material has been described as 200 times stronger than structural steel, and highly conductive of electricity. Its low resistance would enable very low-power, low-heat, ultra-fast computer operations in tiny spaces. After that, look for computers running on light instead of the current semiconductors. The speed, low power needs, and tiny size might make our best current models look as quaint as the Eniac.

(continued on page 12)

Disruptive Technology

(continued from page 11)

3. **Off-label use of existing, already-tested medicines:** While the Federal Drug Administration controls standard testing and uses of pharmaceuticals, striking examples of other uses have made news in recent years. The terrible side effects of **thalidomide** on fetuses caused it to be shelved until the discovery that it could be an effective leprosy remedy. **Minoxidil**, an antihypertensive vasodilator medication, was observed to slow or even stop hair loss and actually promote hair regrowth. It was then marketed as **Rogaine**. **Latisse**, now sold as an eyelash grower, was first bimatoprost (marketed in the U.S., Canada and Europe by Allergan, under the trade name **Lumigan**). This prostaglandin analog was first used topically as eye drops to control the progression of glaucoma and in the management of ocular hypertension. **Doxycycline**, a member of the tetracycline group of antibiotics, was discovered over time to be effective for off-label use against bubonic plague, malaria, Rocky Mountain Spotted Fever in children as well as diverse infections lacking suitable antibiotics or resistant to **vancomycin**. The fields of off-label, *i.e.* untested and unapproved uses for well-evaluated remedies, remains enormous, wide open, and exciting.

4. **Uncertified pharmaceutical combinations:** A somewhat-related field is the use of previously untested *combinations* of existing, familiar, well-tested pharmaceuticals. A variation of off-label usage — that perhaps may recur more frequently — arose after the 2010 rejection by the FDA of Qnexa as an obesity-controlling drug. A potentially disruptive backdoor approach involved California doctors prescribing two well-known drugs, the controversial stimulant phentermine with topiramate, already approved for treating epilepsy and migraine, to provide the same effect as Qnexa. "Through a regulatory loophole of sorts, many obesity doctors prescribe two separate drugs that, when taken together, are essentially the same medicine," reported *The New York Times* [Business Day page B1, Friday, 17 Feb 2012] A week later the same paper announced that the FDA's advisory council overturned the earlier ruling by a 10-2 vote, recommending the drug for approval by the full agency at an upcoming hearing. A search for this synergistic effect of yet untried mergers creates almost infinite opportunity for therapies at rather low cost since original development costs and safety testing have often been fully amortized.

5. **Different electricity-generation methods:** The cover story for the March 2012 *Popular Mechanics* featured a kite-style tethered aircraft using a set of horizontal rotors that rely on prevailing winds for both lift and power generation. These might serve at sea and other remote places where conventional wind turbines and transmission lines pose great problems. Still awaiting serious examination is the whole topic of vertical-axis turbines inside silo-like structures and storing their energy using long-established, safe, cheap storage such as compressed-air tanks.

6. **Breakthrough battery technologies:** In the early 20th century, electric cars were almost as common as gasoline models. With advances both in hybrids and battery technology even better than lithium-ion, we may be returning to the electric vehicle era. One such advance is regenerative braking that returns motion energy to the battery. Because of limits on how much regenerated current batteries can quickly absorb, a bank of hefty capacitors is under development to store energy long enough to feed back into existing batteries at an efficient rate.

7. **Skype & magicJack**: magicJack is a device equipped with a standard RJ-11 phone jack that plugs into a USB port on the user's computer. For a small yearly fee, any standard phone can be plugged into that jack, allowing a user to make phone toll-free calls to almost any phone in the US and Canada. The plug lets the phone, in combination with telephony service from the magic-Jack-related YMAX Corporation, provide VOIP (Internet-based) telephone contact. The firm's primary product is this USB plug that houses both electronics and software to place calls via a customer's high-speed Internet source, empowering conventional landline telephones to plug into the computer for calling. The customer can retain an existing telephone number. A family member who winters in Puerto Vallarta, Mexico, calls us through the season via her local friend's Skype service. The audio quality is acceptable, although a Web search offers many tips on how to improve it. Since Skype's 2011 purchase by Microsoft, the Skype video service based in Luxembourg has expanded to offer what its site calls high-definition video as well. Based on watching news feeds to television broadcasters, I consider the video too jerky and loosely-synchronized with the audio to earn the HD rating, but it is still an amazing departure from big camera-equipped vans mounting satellite dishes on the roof

(continued on page 13)

Disruptive Technology

(continued from page 12)

to deliver instant reports from dangerous locations. By the autumn of 2011 there were over 600 million registered Skype users worldwide. When Henry Ford introduced the Model T in 1908, shrewd owners of livery stables quickly sold them. Considering the rise of magicJack, Skype, and their possible competitors, if I owned stock in major telephone services, I would be calling my broker soon.

8. **Skymine®**: Coal and petroleum seem likely to dominate the energy future of the world for another generation, but one process may shape the future of existing electric power generation and determine the future of existing plants. In recent decades coal-washing, fluidized-bed furnaces, and limestone-based flue-gas scrubbers served as the main approaches to cleaning emissions. Despite hopes to the contrary, the somewhat costly *carbon capture and sequestion* (CCS) has made little headway. The pipelines to move carbon dioxide to distant underground voids or undersea rock formations were not built for a number of reasons. One alternative that may reduce the negatives posed by coal combustion seems to be that of the "SkyMine®" system. One of its first demonstrations began in 2011 at a large Portland cement plant in San Antonio, Texas. According to Skyonic's claims, 10 to 99% of CO_2 can be removed from smokestack stack gas, depending on environmental and economic constraints on the power generating firm. The gas is converted to marketable carbonate or bicarbonate substances (even baking soda) for use in bio-algae production. The technology is said to clean SO_x and NO_2 from the flue gas along with heavy metals including mercury. Other by-products of the cleaning include hydrochloric acid, bleach, chlorine, and hydrogen of such quality as to generate a profit for the operator. Retrofitting current plants to this level of clean operation may extend their usable life and enable them to meet proposed new federal environmental requirements limiting mercury emissions. If Skyonic is successful, the coal and electric power industries would benefit most directly, and so would their customers if the costs can be kept low enough. [http://skyonic.com/skymine/]

9. **Natural gas-powered transportation:** In March, 2012, the Chrysler Corporation announced its first hybrid gasoline-natural gas pickup truck. The intended customer is the operator of fleet vehicles. Living in Arizona in the late 1940s I remember a local service that provided butane for rural customers too far from the town's gas distribution. The delivery trucks all ran on clean-burning butane. The engines and crankcase oil reportedly lasted far longer than those of gasoline-powered vehicles. Propane is favored for cooler climates and many forklift trucks powered by it operate inside partly-ventilated warehouses today. The new Dodge pickup engine will start on gasoline from its eight-gallon tank, and then switch over to compressed natural gas (CNG) from the other tank. The fleet operator typically will operate on-site compressors and refill the truck tanks overnight, or as needed from built-up supplies in large tanks. Homeowners would need little training or expensive equipment to supply the family's hybrid car with only a quarterly trip to a gasoline station. Fleets of mass transit diesel-engine CNG buses have operated for many years in San Diego, Las Vegas, Phoenix, and the New York City suburbs with noteworthy success. By 2005 the Lower Merion School District in Ardmore, Pennsylvania, starting with a single bus, had amassed 72 buses and driven six million miles displacing about 1,300,000 gallon of diesel fuel. To qualify as a disruptive technology, methane-powered vehicles would require a changeover only in the *number* employed, but not the type of technology. After so many false starts, the early-2012 gasoline price runup may propel this change. What will a nationwide network of natural-gas stations look like? Time travel back to 1908 might suggest an answer.

Recent growth of the US methane supply and declining prices per delivered therm have led to predictions that this country will soon become a major exporter of natural gas. Some oil industry analysts have suggested the US should join OPEC because of the nation's increased exports of gasoline and diesel in recent years. As a partial solution to economic, environmental, and geopolitical problems, spokespersons about these concerns from competing sides have tended to agree that natural gas can serve as a temporary bridge to a better energy future based on renewables.

(continued on page 29)

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News from Triangle Coalition

National Academies Reports on DOD STEM Workforce Needs

The National Academy of Engineering just came out with a new report discussing the STEM-related workforce needs for the U.S. Department of Defense. The publication, entitled *Report of a Workshop on Science, Technology, Engineering, and Mathematics (STEM) Workforce Needs for the U.S. Department of Defense and the U.S. Defense Industrial Base,* is the summary of a workshop held by a National Research Council committee on August 11, 2011, as part of an 18-month study of the issue.

This 78-page book assesses the STEM capabilities that the Department of Defense (DOD) requires; whether the current DOD workforce and strategy will meet those needs; and recommends strategies that the department could use to help meet its future STEM needs. It includes a discussion of what the committee believes to be the key points raised by workshop participants, a summary of the keynote presentations, and a summary of panel discussions. The committee plans to issue a final report at the conclusion of the study. The report is available for purchase or free download from National Academies at <https://download.nap.edu/catalog.php?record_id=13318>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 15 March 2012, reprinted with permission.)

US Students Need New Way of Learning Science

American students need a dramatically new approach to improve how they learn science, says a noted group of scientists and educators led by Michigan State University professor William Schmidt.

After six years of work, the group has proposed a solution. The 8+1 Science concept calls for a radical overhaul in K-12 schools that moves away from memorizing scientific facts and focuses on helping students understand eight fundamental science concepts. The "plus one" is the importance of inquiry, the practice of asking why things happen around us – and a fundamental part of science.

"Now is the time to rethink how we teach science," said Schmidt, University Distinguished Professor of statistics and education. "What we are proposing through 8+1 Science is a new way of thinking about and teaching science, not a new set of science standards. It supports basic concepts included in most sets of state standards currently in use and compliments standards-based education reform efforts."

The renowned group of scientists has met with Schmidt in an effort to rethink how science should be taught since 2006, when it was originally part of the PROM/SE research project (Promoting Rigorous Outcomes in Mathematics and Science Education) funded by the National Science Foundation.

The 8+1 concepts were derived from two basic questions: What are things made of and how do systems interact and change? The eight concepts are: atoms, cells, radiation, systems change, forces, energy, conservation of mass and energy, and variation.

Traditionally, science in the United States has been taught in isolated disciplines such as chemistry, biology and physics without clear connections being made between the subjects. The 8+1 effort encourages K-12 teachers to use the eight science concepts to build understanding within and between their courses as students advance through the grades.

"The natural world seems to operate through these laws and concepts, but when it comes to schooling we don't teach children these laws and then show how these apply in different situations," Schmidt said.

Simon Billinge, an 8+1 committee member and professor of applied physics and mathematics at Columbia University, said the aim is for students to see, for example, the physics within biology and the chemistry within physics, so they can gain an understanding of science that transcends disciplinary lines.

Today's frontiers in science often occur at these disciplinary edges. Aided by the explosion in technology and scientific discoveries, new fields are arising that were hardly imagined a generation ago such as synthetic biology, digital organisms, and genomics.

Most states are participating in a process to develop new K-12 science standards that are more relevant, coherent and based on international benchmarks.

Stephen Pruitt, vice president of Achieve, a nonprofit organization managing the state-led effort, said 8+1 Science can work hand-in-hand with his organization's effort – Next Generation Science Standards – "to change

(continued on page 15)

Triangle Coalition

(continued from page 14)

the way we think about science education." "The emphasis is about helping students learn key concepts in science, rather than just facts," Pruitt said.

Results from the 2009 National Assessment of Educational Progress show only 34 percent of fourth-graders and 21 percent of 12th-graders were proficient in their science knowledge. Internationally, U.S. students ranked a mediocre 23rd in their science knowledge among countries studied by the Program for International Student Assessment.

Visit <www.8plus1science.org> for more information, including a research report, film and related classroom posters.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 12 April 2012, reprinted with permission.)

NCSM Publishes Implementation Recommendations for Common Core Math Standards

The National Council of Supervisors of Mathematics (NCSM) recently released a set of recommendations for the broad mathematics education community, as well as agencies, foundations and other interested parties regarding important steps to achieve the goals of the Common Core State Standards for Mathematics (CCSSM) initiative in order to improve mathematics learning opportunities for all students.

The recommendations are the outcome of a series of three conferences held in 2011 with support from the National Science Foundation to identify actions needed to ensure successful implementation of the CCSSM. In subsequent work, leaders of the conference projects collaborated to produce a common set of priority recommendations spanning the three conference themes: curriculum, professional development, and assessment.

The overarching recommendations include:

1. Ensure that the Standards are a Living Document.
2. Ensure that the CCSSM, as Implemented and Assessed, Keeps the Promise of BOTH Career and College Readiness.
3. Adapt and Create Materials that Capitalize on Present and Emerging Technologies to Support CCSSM Implementation.
4. Promote Research-Based Opportunities for Teacher Learning Aligned with the CCSSM.
5. Ensure the Content and Quality of the Mathematical Tasks Used in High-Stakes, as well as Classroom Assessments.
6. Support Research to Monitor and Learn from CCSSM Implementation.

A three-page document, "An Agenda for Action: Implementation of the Common Core State Standards for Mathematics," can be accessed online at <http://www.mathismore.net/resources/MovingForward/Agenda.pdf>.

NGA Brief Highlights Advantages of Informal Science

While the United States remains the world hub of science and technology capacity, its dominance is being challenged by the fast growth of science, technology, engineering and math (STEM) talent in Asia and other parts of the developing world, according to a new issue brief released by the National Governors Association.

Currently, the increase of students pursuing studies and careers in STEM lags. The 13-page brief, entitled *The Role of Informal Science in the State Education Agenda,* looks at a type of innovation that complements other important initiatives. Informal science education — which largely takes place outside the classroom at museums, science centers and other institutions — is an often overlooked tool that can help states achieve their goals. Activities for informal science education include: sustained student learning beyond the classroom; limited-duration programs that compliment classroom learning; teacher professional development programs; and bringing resources to the classroom and student.

"Informal science education can occur year round through a variety of activities," said NGA Executive Director Dan Crippen. "States can make informal science an integral item on their education agendas and improve the prospect of achieving their STEM goals."

To help states make informal science a part of their state STEM agenda, the NGA brief includes the following recommendations:

- Explicitly include informal science education on their agenda of actions to improve STEM literacy and proficiency among the state's youth;

(continued on page 16)

Triangle Coalition

(continued from page 15)

- Continue to support quality informal science programs in the state such as those offered by museums and science centers;
- Encourage districts to support more project-based STEM learning in afterschool environments; and
- Encourage the governor's STEM council or state education agency to oversee the creation of an on -line catalogue of informal science activities offered throughout the state and a compendium of program evaluations.

The NGA brief can be accessed online at <http://www.nga.org/files/live/sites/NGA/files/pdf/1203INFORMALSCIENCEBRIEF.PDF>.

Countries that Best Prepare Math Teachers Share Similarities

Countries that best prepare math teachers meet several key conditions generally lacking in the United States, according to the first international study of what teacher preparation programs are able to accomplish. The International Association for the Evaluation of Educational Achievement (IEA) study, led by Michigan State University, suggests that in countries such as Taiwan and Singapore, future math teachers are better prepared because the students get rigorous math instruction in high school; university teacher-preparation programs are highly selective and demanding; and the teaching profession is attractive, with excellent pay, benefits and job security.

The Teacher Education and Development Study in Mathematics, or TEDS-M, provides strong evidence of the benefits of teacher-preparation programs at colleges and universities. The six-year study was funded by the National Science Foundation, which provided $4.2 million, as well as IEA and the participating countries.

"Some critics of teacher education believe you can bypass colleges of education and prepare teachers in an easier, faster way, but our study doesn't support that," said Maria Teresa Tatto, international study director and MSU associate professor of education. "In Taiwan, for example, nobody graduates without the demonstrated ability to teach mathematics," she said. "Here in the United States, far too many of our graduates lack the knowledge of mathematics and how to teach it, which they will need as they begin to teach."

The researchers collected data from representative national samples that included about 500 higher education institutions in 17 countries that prepare primary and secondary school teachers. Some 22,000 future teachers were surveyed and tested, and 5,000 instructors were also surveyed. The full data from the report will be published soon on the IEA's website, <http://rms.iea-dpc.org>.

The researchers looked at how well the teaching students knew math and how much they knew about how to teach it. The differences between top and bottom scoring countries were very large, Tatto said. Taiwan and Singapore did far and away the best in preparing math teachers. Russia also scored highly. Poland, Switzerland and Germany did well partly because they rely more on specialist teachers in lower grades. The United States generally finished below this group, but above other countries that scored way below the international average, Tatto said.

John Schwille, a researcher on the project and MSU education professor, said the results offer grounds for optimism about what can be done to improve teacher preparation and overcome a climate of skepticism. The study, he added, is in part a response to the belief among many in the United States that teachers are "born and not made, so why are we wasting our time on university programs?" Critics argue that university-based teaching programs are costly and take longer than the alternative of just hiring talented liberal arts graduates and putting them more directly in classrooms.

But this argument doesn't hold up, Schwille said. "There are some 'born' teachers, sure, but not enough to fill the classrooms," he said. "So you're going to have to prepare them. And the countries that do it best rely on university-based teacher education programs."

The international research team also included MSU professors Sharon Senk and Mark Reckase; MSU alumnus Michael Rodriguez; Kiril Bankov from the University of Sofia in Bulgaria; Lawrence Ingvarson, Glenn Rowley and Ray Peck from the Australian Council for Educational Research; a group of survey and sampling specialists from IEA; and mathematicians and mathematics educators worldwide who served as advisers.

To learn more about the IEA study and its conclusions, visit <http://teds.educ.msu.edu/>.

(*Editor's Note*: The preceding three items were excerpted from the Triangle Coalition STEM Education Bulletin for 19 April 2012, reprinted with permission.)

(continued on page 17)

Triangle Coalition

(continued from page 16)

Research Findings Emphasize Implementation of Common Core Math Standards

Dr. William Schmidt of Michigan State University released key conclusions from his research last week detailing how the Common Core State Standards (CCSS) for mathematics can potentially improve the performance of U.S. students if implemented appropriately. In an event co-sponsored by Achieve, Chiefs for Change and the Foundation for Excellence in Education, Dr. Schmidt presented a briefing on his work: *Common Core State Standards Math: The Relationship Between High Standards, Systemic Implementation and Student Achievement*.

Schmidt explained during the event that the CCSS for mathematics strongly resemble the standards of the highest-achieving nations, and that they have more focus, coherence and rigor than most of the state standards they replaced. He also found states with standards most like the CCSS for mathematics have higher scores on the National Assessment of Educational Progress (NAEP), demonstrating that standards – and implementing them well – matter.

"What is clear in the research is that the Common Core State Standards for mathematics are an important improvement over the state standards that they replaced and that to see their full potential realized, they must be implemented well," said Schmidt. "Their consistency with the international benchmark set by top-achieving countries shows that the CCSS are coherent, focused, and rigorous — key attributes of math standards from countries that outperform the U.S. on international assessments."

Schmidt's research also considered the perception of teachers, and what they believe it will take to implement the standards. A representative sample of teachers in each CCSS-adopted state revealed that 90% have heard of the standards; 70% have read them; and more than 90% like the idea of common standards. In order to successfully implement the standards, 40% of teachers indicate they need new textbooks; 60% say they need new online resources for students; and more than 30% report they have not participated in any sort of activity preparing them for the implementation of the CCSS for math.

"Because the Common Core State Standards demand such a fundamental shift in classroom instruction, if implemented well, they will increase student achievement and close achievement gaps," said Michael Cohen, President of Achieve. "We must now focus on supporting our teachers and the education community as they work toward full implementation across all grades."

The briefing challenges the education community to systemically implement the CCSS and demonstrate a clear commitment that all children will have the opportunity to learn challenging math content. If these conditions are met, the data suggest that the Common Core State Standards for mathematics can potentially improve student achievement. The PowerPoint slides of Schmidt's presentation can be accessed online at <http://www.achieve.org/CCSS-schmidt-research>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 10 May 2012, reprinted with permission.)

NAEP Results: Modest Gains in Eighth Grade Science Scores

The 2011 National Assessment of Educational Progress (NAEP) results revealed the average eighth grade science score increased over the last two years, from 150 in 2009 to 152 in 2011. The National Center for Education Statistics (NCES) released the scores on Thursday, 10 May 2012, in the 2011 Nation's Report Card. Scores rose among public school students in 16 of 47 states that participated in both 2009 and 2011, and no state showed a decline in science scores from 2009 to 2011.

While the percentage of students performing at the *Basic* and *Proficient* levels increased, there was no change in the percentage of students at the *Advanced* level. In response to this finding, Secretary of Education Arne Duncan said in a statement, "This tells me that we need to work harder and faster to build capacity in schools and in districts across the country. We have to do things differently, that's why education reform is so critical."

Compared to the 2009 scores, the achievement gap narrowed slightly among both Hispanic students and black students in 2011, with the groups improving average scores by five points and three points, respectively. However, the gender achievement gap remains unchanged with male students scoring an average of five points higher than female students in 2011.

"The gains are encouraging, but the racial and gender gaps show a cause for concern," said David Driscoll, chair of the National Assessment Governing Board, which sets policy for NAEP. "In order to compete in globally competitive and expanding fields like technol-

(continued on page 18)

Triangle Coalition

(continued from page 17)

ogy and medicine, we must make sure we give our students the tools necessary to excel in an important subject area."

The income-level achievement gap also persists from previous years with students from higher-income families continuing to perform better than those from lower-income families.

Students in classes with higher frequencies of hands-on science projects also scored higher on the NAEP assessment than students who did not often participate in such activities. Two percent of students had teachers who said they never or hardly ever had students perform hands-on tasks, and these students had the lowest average score.

In a study to be released in late 2012, the NAEP Science 2011 results will be compared to those of the 2011 *Trends in International Mathematics and Science Study* (TIMSS). The study will also include the results of the NAEP eighth grade mathematics assessment to allow for international comparison in both subjects.

The 2011 NAEP Science results are based on a representative sample of 122,000 public and private school eighth grade students from all 50 states, the District of Columbia, and the Department of Defense Schools. This was the first time all 50 states and the District of Columbia agreed to participate in the NAEP science assessment. To learn more about the NAEP Assessments and the 2011 Science results, visit <www.nagb.org/science2011> or <www.nationsreportcard.gov>.

One-page, individual reports are also available for each of the 50 states, the District of Columbia, and the Department of Defense Schools. Each state snapshot report contains the overall scale score and achievement-level results, as well as student group results. Individual state reports can be accessed online at <http://nces.ed.gov/nationsreportcard/pubs/stt2011/20124678.asp>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 17 May 2012, reprinted with permission.)

CoSTEM Publishes Draft of STEM Education Design Principles

The National Science and Technology Council's (NSTC) Committee on STEM Education (CoSTEM) has published a draft of "Design Principles for Federal STEM Education Investments." CoSTEM is currently in the process of developing a 5-year Federal STEM education strategic plan, as called for by the America COMPETES Reauthorization Act of 2010. This draft of design principles will inform the final version of the plan, which the committee plans to release later this year.

In December 2011, CoSTEM published an inventory of Federal programs and investments in STEM education. The inventory determined that Federal agencies are making 252 distinct investments in STEM education for a total of $3.4 billion. The portfolio concluded that no programs were duplicative, and identified only a few programs with similar objectives, target audiences, products, and STEM fields of focus. In February 2012, CoSTEM released a progress report that provided an overview of the strategic plan and its development process. The final strategic plan will "describe the approaches that will be taken by each participating agency to assess the effectiveness of its STEM education programs and activities." The CoSTEM draft is available online at <http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc_federal_stem_education_coordination_report.pdf>.

New NRC Report Findings Could Improve Undergraduate Science and Engineering Teaching

Discipline-based education research (DBER) has generated insights that could help improve undergraduate education in science and engineering, but these findings have not yet prompted widespread changes in teaching practice, says a new report from the National Research Council. Science and engineering faculty, institutions, disciplinary societies, and professional societies should all support high-quality DBER and the adoption of the evidence-based teaching strategies that have emerged from it, the report says.

DBER is a collection of related research fields that investigate how students learn in particular scientific disciplines and identify ways to improve instruction. This research is emerging in many scientific disciplines, including physics, chemistry, biology, the geosciences, and astronomy, as well as in engineering. DBER combines the expertise of scientists and engineers with methods and theories that explain learning. A DBER scholar in physics, for example, might investigate how students learn concepts such as force or acceleration and try to identify effective ways for instructors to teach these concepts.

Scholars in all DBER fields share the goal of improving teaching and learning by using findings from empirical research. Although they have made inroads in terms

(continued on page 19)

Triangle Coalition

(continued from page 18)

of establishing their fields, the report says, these scholars still face challenges in identifying pathways for training and professional recognition. And findings from DBER have not yet led to widespread change in the teaching of undergraduate science and engineering.

Notable research findings from DBER on undergraduate teaching and learning include:

- Student-centered learning strategies can enhance learning more than traditional lectures.
- Students have incorrect understandings about fundamental concepts — particularly phenomena.
- Students are challenged by important aspects of the domain that can seem easy or obvious to experts.

The report recommends that institutions and professional societies support venues for DBER scholars to share their research findings. In addition, they should support faculty efforts to use evidence-based teaching strategies in their classrooms and work together to prepare future faculty who understand research findings on learning and teaching.

Future directions for DBER investigations should include research that compares learning among various student populations; longitudinal studies on how students acquire and retain understanding (or misunderstanding) of concepts; studies that investigate student outcomes other than test scores; and studies of organizational and behavior change that could aid the translation of DBER findings into practice. The study was sponsored by the National Science Foundation and is available for free download or purchase of a hard copy at <https://download.nap.edu/catalog.php?record_id=13362>.

(*Editor's Note*: The preceding two items were excerpted from the Triangle Coalition STEM Education Bulletin for 24 May 2012, reprinted with permission.)

STEM Disciplines Dominate the 15 Most Valuable College Majors

Forbes highlighted the current 15 most valuable college majors and it comes as no surprise that the list predominantly concentrates on fields involving science, technology, engineering, and mathematics (STEM). To rate the majors, PayScale analyzed the compensation of 120 college majors along with U.S. Bureau of Labor Statistics growth projections through 2020 and ranked the top majors by salary and growth opportunities.

Biomedical engineering ranked top of the list, with a median starting salary of $53,800, an average mid-career salary of $97,800, and job growth projected at 61.7%. Engineering fields make up one third of the most valuable majors and the rest require strong skills in science, technology and mathematics:

2. Biochemistry
3. Computer Science
4. Software Engineering
5. Environmental Engineering
6. Civil Engineering
7. Geology
8. Management Information Systems
9. Petroleum Engineer
10. Applied Mathematics
11. Mathematics
12. Construction Management
13. Finance
14. Physics
15. Statistics

Business-Higher Education Forum to Launch New Undergraduate STEM Education Initiative

On 11 June the Business-Higher Education Forum (BHEF) kicked off a new initiative designed to improve undergraduate STEM education through collaborative projects between industry and higher education. At a special event, *The Introduction of a New Industry-Higher Education Solution for the NextGen Workforce*, in the Russell Senate Office Building, BHEF announced twelve regional workforce projects in today's high-demand STEM fields. These projects will center on cybersecurity, big-data, life sciences, water, energy, engineering, and entrepreneurship. A diverse panel of leading national industry and higher education experts will also discuss how these projects are poised to drive change for their constituencies.

The projects will be based in California, Florida, Iowa, Kentucky, Maryland, Massachusetts, Missouri, New York, Ohio, and Wisconsin. These BHEF initiatives will build learning incubators for undergraduates in the education pipeline and will contribute to recommendations recently made by the President's Council of Advisors on Science and Technology (PCAST), specifically calling for greater attention on the first two years of college and on the need for one million additional STEM graduates over the next ten years. They also respond to the recommendations of the President's Council on Jobs and Com-

(continued on page 20)

Triangle Coalition

(continued from page 19)

petiveness, which include increasing the number of industry-driven undergraduate research internships and production of engineering degrees nationally.

BHEF partners, including the Aerospace Industries Association, American Chemical Society, American Council on Education, Triangle Coalition Member – the American Society of Engineering Education, Association of American Universities, Association of Public and Land-grant Universities, National Defense Industries Association, Semiconductor Industries Association, and TechNet, have committed to a set of joint priorities and strategies to better align the individual and combined efforts of the undergraduate community around common goals, thus creating an equal voice for industry, research, and academia.

This work is part of BHEF's STEM Higher Education and Workforce Project, which aims to identify new forms of collaboration among business and industry, higher education, and government to increase the persistence of students, particularly women and underrepresented minorities, who graduate in STEM fields; deepen STEM knowledge and skills; and strengthen the alignment of undergraduate STEM education to workforce needs.

NMSI's UTeach Program Reaches Enrollment Milestone of 5,500 Students

The National Math and Science Initiative (NMSI) recently announced that its highly acclaimed teacher training program, UTeach, has reached the enrollment milestone of more than 5,500 students and 800 program graduates, creating a new generation of science, technology, engineering, and math (STEM) teachers for the U.S. public school system.

The announcement was made on May 24 at a STEM teacher panel, "America's Future STEMS on Good Teachers: Are We Ready?," which NMSI hosted at the National Press Club in Washington, DC. Leaders also announced that the UTeach program has expanded the program to its 30th university campus, Towson University, near Baltimore, MD.

The UTeach program encourages college students majoring in math, science, or computer science to pursue careers in teaching and enables them to receive full teaching certification without adding time or cost to their degrees. NMSI, in partnership with the UTeach Institute at the University of Texas at Austin, has implemented the program in college campuses across the U.S. since 2008. Eight hundred college students – and potential future teachers – have graduated from the program, which has seen its enrollment nearly quintuple in just four years. NMSI estimates that the first group of UTeach graduates will have taught more than four million students by the year 2020.

NMSI has been a leader in addressing the nation's call for a new pipeline of highly qualified STEM teachers through its UTeach program and through partnerships with national organizations such as 100Kin10, which seeks to recruit 100,000 new math and science teachers in the next 10 years. Teacher training for existing STEM teachers nationwide is also a critical component of NMSI's Advanced Placement Training and Incentive Program (APTIP) and Laying the Foundation program.

"Our nation needs an additional 280,000 math and science teachers by 2015, and the UTeach program is playing a key role in providing those teachers," said Dr. Mary Ann Rankin, President and CEO of NMSI. "The expansion of the program to Maryland underscores that demand for the UTeach program continues to grow around the country and proves that more college students will seek careers as math and science teachers if you provide an approach that makes sense," she added.

Funding for the new program at Towson University was made possible through a $1.33 million grant from the Maryland State Department of Education, which received federal Race to the Top funds. Through the Michael & Susan Dell Foundation, NMSI committed an additional $680,000 in funding, and the University System of Maryland pledged another $300,000 annually.

Findings Say Reducing Undergraduate Debt is Key to Broadening Participation for Latinos in STEM Fields

Reducing undergraduate debt through financial aid policy can increase the number of Latino students who become scientists, engineers, and mathematicians by enabling them to continue to invest in their education beyond the bachelor's degree, according to a new report by the Center for Urban Education at the University of Southern California. Underrepresented students, particularly Latino students, borrow at higher rates to pay for undergraduate degrees, which limits their ability to invest in graduate and professional schools.

"With growing attention to student loan debt, this is the opportune time for lawmakers on both sides of the aisle to consider innovative ways for the federal govern-

(continued on page 21)

Triangle Coalition

(continued from page 20)

ment to support student investments in STEM degrees by providing a more balanced package of loans, grants, work study aid, and community or business sector support," said Dr. Alicia C. Dowd, Associate Professor at the University of Southern California, Co-Director of the Center for Urban Education, and co-author of the report.

The report, *Reducing Undergraduate Debt to Increase Latina and Latino Participation in STEM Professions*, examines the borrowing patterns of undergraduate students and the relation of that debt to enrollment in graduate school. It shows that even low amounts of debt can have a negative impact on graduate enrollment. Latino students with high debt, relative to others in their class, are 17% less likely than students without debt to go on to graduate or professional school. Those with low debt were 14% less likely. In a 2011 report, the National Academies called for a short term goal of doubling participation of African Americans, Hispanics, Native Americans, and other racial-ethnic groups in science, technology, engineering and math (STEM), with long term goals that call for tripling and even quadrupling their enrollment. The Center for Urban Education's report makes it clear this increase is unlikely without addressing the issue of financing undergraduate education.

While increased undergraduate debt is a national concern as it can decrease recent graduates' ability to function in society, this report raises the issue that undergraduate debt is not just a quality of life concern for graduates, but may be negatively impacting the nation's workforce by limiting the number of students who go on to graduate school. A prior report in this series noted increasing participation of Latino STEM students at all degree levels is not just a matter of fairness and social equity, but of workforce need. The Bureau of Labor Statistics projects employment in STEM occupations will increase by 21.3% from 2008 to 2018 – more than double the growth in other occupations. Latinos are the fastest growing demographic group and are projected to make up 25% of the U.S. population in 2020.

Recommendations from the report include:

- Continue and enlarge the federal Pell grant program.
- Reduce the risk of unmanageable debt by keeping interest rates steady at their current levels.
- Expand access to research assistantships, particularly at institutions that serve high numbers of Latinos such as Hispanic Serving Institutions (HSIs) and community colleges.
- Create a STEM focused work-study program
- Explore the potential of Individual Development Accounts (IDAs)
- Monitor the use of Title V HSI-STEM funds to ensure they're promoting Latino student preparation and success in STEM
- Disaggregate analysis of student loan debt by race and ethnicity to monitor borrowing in federal subsidized loan programs

The report comes from a research grant funded by the National Science Foundation and is the fourth in a series. It was written by Dr. Alicia C. Dowd, Associate Professor and co-director at the Center for Urban Education (CUE), and Dr. Lindsey E. Malcom, Assistant Professor at George Washington University. The report is available online at <http://cue.usc.edu/assests/USC%20CUE%20NegativeImpact%20of%20Debt%20on%20Professional%20Preparation%20in%20STEM_May@2012.pdf>.

(*Editor's Note*: The preceding four items were excerpted from the Triangle Coalition STEM Education Bulletin for 7 June 2012, reprinted with permission.)

Immigration Reform Key to US Economic Growth and Bolstering STEM Workforce

In the United States, a significant gap exists between the number of graduates earning degrees in science, technology, engineering, and math (STEM) and the increasing demand for educated workers to fill current and future jobs in these fields. With many of the students who are studying STEM fields in America being born elsewhere, the U.S. risks losing talented students when they graduate due to stringent immigration laws.

A new study by the Partnership for a New American Economy and Partnership for New York City compared ways that foreign countries are shaping immigration policies to boost their economies by attracting highly skilled workers in STEM fields. The report, "Not Coming to America: Why the US is Falling Behind in the Global Race for Talent," recommends reforms for U.S. immigration policy that are necessary to boost the nation's economy by attracting and retaining talented STEM graduates. Currently, the U.S. faces a projected shortfall of 230,000 qualified advanced-degree STEM workers by 2018.

The report identifies three major risks facing the U.S. economy if it does not reform its immigration laws: a

(continued on page 22)

Triangle Coalition

(continued from page 21)

shortage of workers in innovation industries, shortage of young workers, and slow rates of business startup and job creation. As jobs in science, technology, engineering and math (STEM) increase three times faster than other jobs, there are not enough American students entering these fields. The U.S. also faces a shortage of workers as baby boomers retire en masse, and growth in the labor force slows to historic lows of less than one percent. Finally, while new businesses are the biggest driver of job creation, the most recent U.S. Census data shows that business startups have reached a record low.

While other countries in this study, Australia, Canada, Chile, China, Germany, Ireland, Israel, Singapore and the United Kingdom, have adopted policies to attract immigrants necessary to drive economic growth, the basic policy framework governing immigration in America has remained unchanged for nearly fifty years. The report emphasizes that the U.S. can no longer afford to take a back seat in the race for the workers it needs with an antiquated immigration policy. The report concludes by recommending six immigration reforms the U.S. can adopt to resume its position as the magnet for the world's most talented and necessary workers:

1. Provide visas to the STEM graduates educated in American universities.
2. Award more green cards based on economic needs.
3. Create a visa program for foreign entrepreneurs to build their firms in the US.
4. Let American companies hire the highly educated workers they need.
5. Give industries that depend on workers just starting up the economic ladder, such as agriculture and tourism, access to foreign workers when they cannot find Americans to fill jobs.
6. Allow local governments to recruit more immigrants to meet regional needs.

Policy makers have considered numerous bills that would work to solve this issue and align immigration laws with many of these recommendations. The SMART Jobs Act (S. 3192), introduced in May 2012 by Senators Lamar Alexander (R-TN) and Chris Coons (D-DE), would create a new student-visa category for graduate students pursuing STEM degrees and allow them to legally reside in the country for one year following graduation with the possibility of becoming a "legal permanent resident" once they are employed.

The full report, "Not Coming to America: Why the US is Falling Behind in the Global Race for Talent," can be found at <www.renewoureconomy.org/not-coming>.

Innovative Science Assessment Reveals Students Struggle to Explain Scientific Results

For the first time, the National Assessment of Educational Progress (NAEP) Science Assessment measured how well students apply their understanding of science in real-life contexts. The results of the 2009 Science Assessment were released this week in the Nation's Report Card Science in Action: Hands-On and Interactive Computer Tasks. The report revealed that America's fourth, eighth, and twelfth graders can conduct science investigations using limited data sets, but many students lack the ability to explain results. The report shows that students were challenged by parts of investigations requiring more variables to manipulate, strategic decision-making in collecting data, and the explanation of why a certain result was the correct conclusion.

The new interactive computer tasks and updated hands-on tasks that involve more open-ended scenarios were administered as part of the 2009 science assessment by the National Center for Education Statistics. The findings provide important insights for educators and policymakers who are looking for academic approaches that support careers in science, technology, engineering, and mathematics (STEM) fields, and encourage scientific inquiry.

"Science is fundamental to education because it is through scientific inquiry that students understand how to solve problems and ultimately how to learn," said David Driscoll, chairman of the National Assessment Governing Board, which sets policy for NAEP. "So it's tragic that our students are only grasping the basics and not doing the higher-level analysis and providing written explanations needed to succeed in higher education and compete in a global economy."

The purpose of using hands-on and interactive computer tasks in testing is to determine whether students can solve problems as a scientist would and require students to perform actual science experiments. Interactive computer tasks require students to solve scientific problems in a computer-based environment, often by simulating a natural or laboratory setting.

"This innovative format allows for a richer analysis than a paper-and-pencil test," Driscoll said. "Interactive computer tasks allow us to more deeply examine stu-

(continued on page 23)

Triangle Coalition

(continued from page 22)

dents' abilities to solve problems because the tasks generate much more data."

Only 53 percent of 12th graders reported that they were enrolled in a science course, and only 28 percent reported writing a report on a science project at least once a week. Ninety-two percent of fourth graders and 98 percent of eighth graders had teachers who reported doing hands-on science activities with students at least monthly. Thirty-nine percent of fourth graders and 57 percent of eighth graders had teachers who reported having at least a moderate emphasis on developing scientific writing skills.

The assessment measures science skills in a number of ways. Some questions use a model known as "predict-observe-explain" to examine students' ability to combine their science knowledge with real-world investigative skills.

To correctly predict, students had to provide an accurate description of what might happen in a situation. For instance, when asked what kind of sunlight conditions were needed for a sun-loving plant and a shade-tolerant plant, 59 percent of fourth graders showed understanding that different plants have different sunlight needs.

Through the observe phase, students watched what happened as they conducted their experiments. Eighty percent of fourth graders made straightforward observations and tested how fertilizer and sunlight affected plant growth, but only 35 percent could perform a higher-level task that required them to make decisions about the best fertilizer levels for a sun-loving plant.

Students were then asked to explain what they had observed by interpreting data or drawing conclusions. Across all grade levels, a majority of students could observe, but far fewer could predict or explain. In fourth grade, fewer than 50 percent of students could explain why they selected a given fertilizer amount to support plant growth and use evidence to support their answer. At grade 8, 88 percent of students could correctly identify which liquid flowed at the same rate as water at a given temperature, while only 54 percent could support this answer with a written explanation of the evidence.

At twelfth grade, 64 percent of students could recommend the site for a new town based on information provided about water quality, while 75 percent of students could perform a straightforward investigation to test the water samples and accurately tabulate data. But only 11 percent were able to provide a valid recommendation and support their conclusions with details from the data.

Science in Action: Hands-On and Interactive Computer Tasks from the 2009 Science Assessment is available at <www.nationsreportcard.gov>. Visit <www.nagb.org/science/hots-icts/> for more information and materials on recent results. Dive deeper into the tasks by visiting the NAEP interactive website at <http://nationsreportcard.gov/science_2009/>.

New Analysis Estimates Costs of Implementing New Standards

The total cost of implementing new common standards in math and English Language Arts will range from $3 billion to $12 billion, depending on how states approach that challenge over the next several years, according to a report released on May 30 by the Thomas B. Fordham Institute. *Putting a Price Tag on the Common Core: How Much Will Smart Implementation Cost?* estimates the implementation cost for each of the forty-five states (and the District of Columbia) that have adopted the Common Core State Standards. Since states and districts are already spending money on related items like textbooks and professional development, the report explains, *new costs* could range from less than zero to about $8 billion, with a "balanced" approach costing less than $2 billion in the aggregate.

Authors Patrick J. Murphy of the University of San Francisco and Elliot Regenstein of Education Counsel LLC show that costs naturally depend on how states approach implementation, and illustrate this with three models:

- ***Business as Usual.*** This "traditional" (and priciest) approach to standards implementation involves buying hard-copy textbooks, administering annual student assessments on paper, and delivering in-person professional development to all teachers.
- ***Bare Bones.*** This lowest-cost alternative employs open-source instructional materials, annual computer-administered assessments, and online professional development via webinars and modules.
- ***Balanced Implementation.*** This is a blend of approaches, some of them apt to be effective as well as relatively cost-efficient.

(continued on page 28)

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Alex Wellerstein, "A Tale of Openness and Secrecy: The Philadelphia Story," *Phys. Today*, **65**(5), 47-53 (May 12).

The subtitle of this article derives from the location of the group of nine physicists who conducted a seminar on the design of nuclear weapons in 1946 based on published literature and the Smyth Report, then sought to publish the proceedings of their seminar in order to restore the openness characteristic of science to this topic in view of the limitations of secrecy during World War II. Wellerstein observes that "the Philadelphia Story was just the first of a recurrent problem, one not limited to the atomic bomb alone . . . as scientists have mulled over the implications of publishing, for example, potentially dangerous data about genetically engineered H5N1 flu viruses" (the topic of the Infusion Tips column in our Winter 2012 issue and of a story on p. 32 of this issue).

2. Kevin Heng, "The Study of Climate on Alien Worlds," *Am. Sci.*, **100**, 334-341 (Jul-Aug 12).

By observing the spectrum of light from a distant star during transits and eclipses of its planets, scientists can now determine the atmospheric constituents of the planets. Light during an eclipse is from the star alone, and subtracting this from the star plus a planet gives the planet's spectrum alone, and from this spectrum the atmospheric constituents can be determined. Moreover, repeated measurements over several orbits produce a power spectrum to identify periodic changes. This article focuses on measurements that have been done on two "big Jupiters."

3. David P. Jackson, Priscilla W. Laws, and Scott V. Franklin, "An Inquiry-Based Curriculum for Nonmajors," *Science*, **335**, 418-419 (27 Jan 12).

These three authors describe the "Light, Sight, and Rainbows" unit of their Explorations in Physics curriculum. The goal of this curriculum is to increase the 28% scientific literacy rate of U.S. adults by giving college nonscience majors a taste of how science is done through guided inquiry experience followed by a student-designed project. This curriculum was one of 15 awarded the 2011 AAAS *Science* Prize for Inquiry-Based Instruction.

An editorial on p. 380 of the same issue by *Science* Editor Bruce Alberts explains that these prizes are to "support a rethinking of science education that is consistent with the new *Framework for K-12 Science Education*" and that the 2012 contest will include curricula in engineering as well as science and will include the advanced high-school level as well as college. Alberts championed the 1996 *National Science Education Standards*, which also emphasize the importance of inquiry, when he was President of the National Academy of Science (see cover stories of our Spring 1997 and Spring 2007 issues).

4. Special section on "The Future of the Environment," *Pop. Sci.*, **281**(1)(Jul 12).

Tom Clynes, "The Battle," pp. 36-43, 80: The "battle" is that between believers in and deniers of global climate change resulting from human carbon dioxide emissions, and this article profiles both "sides": Michael Mann, Al Gore, Peter Gleick, the Union of Concerned Scientists, and the Intergovernmental Panel on Climate Change on the "pro" side, and Steve Milloy (JunkScience.com), Marc Murano (ClimateDept.com), Myron Ebell (Competitive Enterprise Institute), the American Tradition Institute, Joe Bast (Heartland Institute), and Senator James Inhofe (R-OK) on the "con" side. In the middle is an evangelical climate scientist named Katherine Hayhoe. Clynes finds that some of the skeptics are having difficulty denying the climate change they're experiencing – but not Sen. Inhofe.

David Roberts, "Climate Change is Already Happening: Now It's Time to Get Ready," pp. 44-45: Although United Nations "climate negotiators" have sought to limit atmospheric carbon dioxide to 450 ppm, so that the temperature increase relative to preindustrial levels will be less than 3.6^{o}C (1.6^{o}C of which has already occurred), business-as-usual would mean a temperature increase of 10^{o}C by 2100, along with a six feet sea level rise, and an Earth half uninhabitable by 2300, according to some climate models. We won't know exactly what will happen until it does, but when it does, we will need to be prepared for it.

Kalee Thompson, "Build Smarter Cities," pp. 46-47: Accommodating a population of nine billion can be done more efficiently by locating employment in city centers to minimize commuting, building multifunctional homes, sharing electric cars, powering neighborhoods by mi-

(continued on page 29)

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (Penguin Press, New York, 2012). 422 pp. ISBN 978-1-59420-328-2.

Lists of American inventors usually include Morse, Goodyear, Bell, and Edison. In the near future they should add Claude E. Shannon. MIT dean Vannevar Bush, coordinator of over 6000 scientists in the Manhattan Project and other massive efforts, noticed him early as "a man who should be handled with great care." William Shockley, developer of the transistor, and others recognized him not only as a brilliant graduate student, but "something else entirely." In the late 1930s when Shannon considered taking flying lessons, one MIT professor discouraged it because of the danger of his crashing and the loss of young Shannon to the entire scientific community. He was seen as a resource that needed to be protected from such risk.

Bush, inventor of a "differential analyzer," hired Shannon to run this early calculator of differential equations. Shannon delighted in re-designing its gears, rods, and relays for various purposes, while initiating a kind of computer programming reminiscent of Babbage's difference engine a century earlier. One of history's most fortuitous transfers took place in 1937 when Shannon left MIT briefly to work at the old Bell Labs facility on West Street in lower Manhattan. There he applied such Boolean algebra terms as "AND" and "OR" to circuits, switches, and telephone equipment while mixing them with what became the familiar binary computer logic's 0 and 1. Returning to MIT, with Bush's encouragement he wrote up his thoughts in a form that Gertner describes this way:

> Shannon's slender and highly mathematical paper, about twenty-five pages in all, would ultimately be known as the most influential master's thesis in history. In time, it would influence the design of computers that were just coming into existence as well as those that wouldn't be built for at least another generation.

Thus it is appropriate to view Shannon with his "information theory" as the mathematical father of the digital age as much as Shockley was the father of practical technology empowering the modern era.

Gertner's book spins biographies, geography, and technology of the Bell System into a well-told story. Technical explanations are incorporated into the text just enough to welcome a variety of readers, neither talking down to any of them or leaving them lost in a blizzard of jargon. Yet, scientists and engineers will also find enough of the "how and why" connections in this story to hold their interest. The telling marches along with hints of information to be explored in later chapters. Gertner shows a gift for supplying enough facts without becoming enmeshed in detail. For those looking for more of the latter, 45 pages of endnotes, amplifications, bibliographies, interviewee lists, and other oral history resources testify to the massive research supporting this work. Avoiding sensationalism, he deals with Shockley's successes followed by failures and descent into paranoia and appalling racism. Elsewhere with gentle humor he mentions details of the hobbies and personal life of dozens of creative people who at some time became involved with Bell Labs. Interviews with them or their survivors enliven the narrative.

One of the strengths of *The Idea Factory* is its weaving together a readable fabric of the leadership traits and quirks, architectural planning of lab facilities, commercial goals of an ever-more-complex national system, limits on the corporate system imposed by monopoly status, and patriotic wartime contributions.

As research shifted from the crowded West Street lab to a huge H-shaped facility in Murray Hill, New Jersey, the nature of cooperation itself changed. The new design encouraged face-to-face contact in the 700-foot-long corridors by scientists and engineers from *diverse* disciplines. The technicians were also expected to be expert specialists in their narrow fields, and therefore enjoyed a level of respect not always found in academic hierarchies. Researchers were encouraged to spend 20% of their time working in areas outside their daily responsibilities. One valued staffer managed to spend more than the fifth of his time riding a unicycle through the Murray Hill hallways, sometimes while also juggling.

For the most productive decades of Bell Labs, there was a reciprocal flow of talent among the laboratory, academia, and government. One factor shaping this "pre-competitive era" and its easy movement was the federal government's tolerance of the AT&T's violation of the 1890 Sherman and 1914 Clayton Anti-Trust Acts. The price for this flexibility? The Bell System had to allow most of its patents to be used by non-Bell industries. It

(continued on page 26)

REVIEWS

(continued from page 25)

was also expected to fully support military technology. To avoid further anti-trust attention, AT&T chose not to compete with the nascent computer manufacturing business sometimes called "IBM and the seven dwarfs." Those seven derisively indicated were Burroughs, Univac (Sperry-Rand), NCR, CDC, GE, RCA and Honeywell.

Until 1956, throughout most of the US and Canada, the gigantic Bell System consisted of [1] AT&T as the mother ship, [2] Long Lines (tolled distance service), [3] regional operating companies (New England Telephone, Mountain States Telephone & Telegraph, *etc*.), [4] Western Electric, the supply coordinator, and [5] Bell Labs as solution generator and designer for the future. The Labs division included, besides West Street and Murray Hill, smaller sites at Holmdel, Crawford Hill, Whippany, Succussuna, and Chester, New Jersey. Pilot plant operations abounded elsewhere. In a part-time job in high school at Coolidge, Arizona, I was the custodian for the county-wide dial switching facility. It was then serving as the first test site for the new "toll dialing" to be rolled out nation-wide. I can still recall being alone in the lightless room with the sound of electro-mechanical switches as they connected callers and recipients. Bell Labs workers sometimes visited us, as did Western Electric installers from Phoenix, and Long Lines men from out of state.

In an oxymoronic legal action, "The 1956 Consent Decree," Western Electric was separated from the Bell System's monopoly. As a janitor in 1953, I had been required to use Bell System brand scouring powder and lint -free cloths, and even their proprietary dust-free broom/mop device. After 1956, however, local telephone exchanges were free to buy Bon Ami or Bab-O cleanser at Safeway.

Details of the consent decree and much more of the complex history and achievement of Western Electric can be found at <http://www.porticus.org/bell/westernelectric_history.html>. In summary, the 1949 antitrust case by the Department of Justice resulted in this 1956 consent decree: It ordered the Bell System to divest all of its non-telephone activities except those involving national defense. Ironically, the same year a trio from Bell Labs, John Bardeen, William Shockley, and Walter Brattain were awarded the Nobel Prize for their work on the transistor.

Princeton resident Gertner, who grew up in walking distance from the Murray Hill lab, succeeds in giving the reader a balanced tribute to the stupendous achievements of Bell Labs. He dealt with biographical sketches of key participants, synergism among various STEM disciplines that was also shaped by socioeconomic forces, and the claims for and against monopoly. He relates the impacts of Bell's research on many other industries, and covers causes of both the peak and eventual decline of Bell Labs to its present status. In recent television interviews he insisted the lab sites still contribute cutting-edge work, despite a much-reduced staff. The loss of income from the other Bell divisions including Western Electric, has forced a relative shrinkage of the funding and changed the main purposes of the Labs division under management by Alcatel-Lucent. (See <http://www.alcatel-lucent.com/wps/portal/BellLabs/AboutBellLabs>). Bell Labs now has eight research centers located in the United States, France, Belgium, Germany, Ireland, India, China and South Korea and claims to hold 27,600 active patents worldwide, including over 2,100 patents granted during 2009.

The influence of creative offerings from the Bell System continues to spread. A division of Western Electric that was spun off in 1929 to become the huge employee-owned Graybar Electric Company. Other work by the Bell Labs more recently gave new direction to Corning as major supplier of ultra-pure glass fiber for light-transmitted communications. Fairchild and Texas Instruments emerged early as producers of the transistors born at Murray Hill. Post-Eniac computer hardware expanded beyond the most generous prediction as developers employed the Unix, and other programming languages arising from Claude Shannon's work. The Microsoft, Apple, and Linux operating systems can be traced to the same source.

Despite supplying and employing internally so much of early computer hardware and mathematical guidance, even with a lessened threat from antitrust authorities, the heirs to the original Bell System still avoid selling either mainframe or consumer-level computers. Here is a partial list of some of other Labs achievements: radar enhancements, vacuum-tube amplifiers for the long-distance land lines and the trans-Atlantic cable and their solid-state successors, pulse code modulation, germanium and other semiconductors leading to silicon-based transistors and integrated circuits, masers and lasers, microwave tower transmission, electronic call switching, Telstar and later satellite communications, the cellular phone network with its texting capability, fiberoptic communications, silicon solar cells, and far more less familiar successes. From 1929 onward there have been 33,000 patents granted to Bell Labs.

(continued on page 27)

REVIEWS

(continued from page 26)

The later chapters follow the careers of many Bell contributors. Several pages deal with impacts of both AT&T policies and external developments that changed both Bell and its growing horde of rapidly-moving competitors. AT&T's once-commendable goal of a 30-year usable life for every Bell element — from outdoor pole to windowless switching exchanges to desktop dial telephones — left Bell Labs less able to move forward at the speed of its competitors with much shorter product cycles.

I wish I had known more of the contents of this superb book when I was greeted by the chattering switches in the pre-dawn Coolidge office, while I drove past the pole lab at Chester, or spent hours at Whippany with an inventor of one of Telstar's 15,000 components, or daily walked past the former West Street lab site. The pleasure would have been even greater when I visited an immense private Western Electric museum in Corsicana, Texas: The Capehart Communications Collection. (See <http://www.telcomhistory.org/vm/museumsCapehart.shtml>)

Sentimentality might not seem appropriate to most of these pioneers, but surely a bit of nostalgia for those glorious years is forgivable. In a suitable explanation about the triumphant early years, a Bell laser scientist, Herwig Kogelnik, still applies: "It's the interaction between fundamental science and applied science, and the interface between many disciplines, that creates new ideas."

- John D. White

Alan E. Walter, *Radiation and Modern Life* (Prometheus, New York, 2004). 336 pp. $28.98. ISBN 1-59102-250-9.

My interest in nuclear energy and radiation was stimulated in the summer of 1977 when I completed a course in nuclear science at Penn State. Since then I have been a strong supporter of nuclear power and applications of nuclear technologies. Nuclear science issues are a hot topic in the media, in particular those dealing with nuclear weapons proliferation. *Radiation and Modern Life* describes the advantages of nuclear science applications at a level accessible to the general reader.

Nuclear science is a strong driver of our economy. This is illustrated in chapter 13, titled "Modern Economy." Eleven figures and tables are included in just thirteen pages. One revealing figure is found on page 244, which indicates that in the U.S., radiation technologies were second in job creation in 1995 only to the banking industry, ahead of electronics, printing and publishing, hotels, and four other major industries.

The opening chapters of the book describe our dependence on radiation technologies and basics of radiation science. The text is accompanied by numerous helpful illustrations. Chapters four through twelve describe applications of radiation technologies in many industries, including agriculture, medicine, transportation, environmental protection, and energy.

During his career the author was the head of the nuclear engineering department at Texas A & M, and he advocates for the expansion of nuclear energy for the production of electricity. In the chapter titled "Electricity" he recognizes the value of renewable energy such as solar and wind but identifies the shortcomings of these sources. He explains that a typical 1,000 megawatt nuclear power plant requires five hundred to one thousand acres, while thirty-five thousand acres are needed for a comparable solar plant, and a similar-capacity wind farm requires about one hundred fifty thousand acres. Walter includes an analysis of the government subsidies renewable energy sources have received. "In 2002 wind energy was subsidized by almost the exact amount of the total cost of producing electricity from nuclear power plants."

In a section titled "Issues of Nuclear Power," the problem of nuclear waste storage is addressed. He describes the amount of material currently being stored as "exceedingly small." "If we were to receive all of our electricity from (nuclear power) for the next fifty years, the amount of space needed for the sequestration of the nuclear waste would fit on a football field fifty feet deep." He goes on to indicate that the amount of nuclear waste generated represents less than one percent of the waste generated from equivalent fossil fuel plants. Walter reminds us that all of the nuclear waste that has been generated to date is stored right at the site. He goes on to describe nuclear waste storage proposals as well as the advantages of nuclear generated electricity and the challenges the nuclear power industry faces.

The author describes in detail numerous applications of radiation science. These are summarized in appendixes "A" through "G" on pages 277 through 293. I was surprised to learn that radiation is now being used in place of sulfur in vulcanizing rubber.

The final two chapters, "A Day With the Atom" and "A Glimpse Into the Future," provide information about

(continued on page 28)

REVIEWS

(continued from page 27)

how our daily lives depend on and are affected by radiation. The book contains eighty five figures and numerous illustrations. It is a valuable resource for science teachers and anyone interested in information about nuclear science and uses of radiation.

- Frank Lock

(*Editor's Note*: Frank Lock has written many reviews for this *Newsletter*. He has retired from teaching physics at Lemon Bay High School (FL).)

Richard N. Steinberg, *An Inquiry into Science Education, Where the Rubber Meets the Road* (Sense, Rotterdam, 2011). xii + 126 pp., paperback. ISBN 978-94-6091-688 -5.

Richard Steinberg is professor of physics and science education at the City College of New York (CCNY). He took the steps needed to be certified to teach physics in a New York City public high school and spent a sabbatical doing this – for, as he states, two reasons: to understand how his undergraduate students at CCNY obtained their backgrounds, and to understand the feedback he was getting from high school physics teachers. He describes his experiences in this "diary of my 12 months away from being a college professor" (p. ix) "as a full time public high school science teacher in a poor neighborhood in New York City." (p. viii) Each of the 12 chapters in this "diary" represents one of those twelve months, though incidents have been regrouped for the sake of coherence of presentation, and the names of the school at which he taught and all of the teachers and students with whom he interacted have been changed.

Steinberg's first "month" is August, when he teaches students in the CCNY Summer Scholars Program, using Lillian McDermott's *Physics by Inquiry*. In the second "month" he moved to UHS, where he found himself immersed in a different educational culture. "Science was something you were told and the reason something was known was because you were told it," he writes (p. 32). The goal of a physics course in a New York State public school is to pass the New York State Regents exam, and Steinberg concluded early on that learning was further hindered by the feeling that instead of being a collection of definitions, formulas, and constants to be memorized, physics is a collection of those elements to be looked up in the reference table students are allowed to use in taking the Regents exam. He further recognized that acceptance of these elements, whether memorized or looked up, without motivation or substantiation precludes real understanding. He found the fallacy of this approach to learning to be "more ingrained than any misconception . . . about . . . content." (p. 36) The biggest barrier to understanding was epistemological – the approach taken to learning.

Steinberg was also frustrated that students repeatedly wanted to be told what to do: "learning was about doing exactly what you are told or repeating back something given by some authority. Understanding something well enough to do it on your own was rarely a student goal." (p. 61) But "if students are to be real learners of science, they . . . need to take charge of making sense of it for themselves," he goes on. "Learning how to think independently, learning how to ask questions and pursue answers, learning how to develop problem solving strategies, and learning how to learn should all be important outcomes of a good education." (p. 66) In contrast with this ideal, Steinberg laments "That students have such difficulty remembering what they were told by their teachers is often noted with real concern. That the goal is to have students simply remember what they were told concerns me more." (p. 68)

"We want our students to be inquisitive, lifelong learners, but we prescribe specifically what they should do . . . in school. We want our students to apply what they learn . . . but we create a classroom environment decontextualized from their lives," Steinberg writes in his concluding chapter. Yet he is not without hope that nothing can be done to provide a more hopeful future. One of the positive things he learned from his year at UHS was getting to know and connecting with students outside of content and outside of class. Were he to have stayed a second year, he would have done more of this, with the expectation that his second year would be better than the first.

- John L. Roeder

Triangle Coalition

(continued from page 23)

The report examines the tradeoffs associated with each strategy and estimates how much the three approaches would cost each state that has adopted the Common Core. The authors point out that, since states already invest billions annually in professional development, assessments, textbooks, and other expenses in connection with existing standards, proper forecasting of Common Core costs should "net out" the sums that states would spend anyway for activities that this implementation process will replace.

(continued on page 29)

Disruptive Technology

(continued from page 13)

Few, if any, futurists claim to have predicted (even a decade beforehand) radar, CB radios, the Soviet collapse, the SONY Walkman, streaming video movies on one's smartphone, affordable flatscreen TVs covering half a wall, the GPS system, cell phones replacing landlines, LED traffic lights, digital TV transmission, a cable-connected nation, or any of the worldwide financial crises since 1929. Traveling through rural Guatemala's highlands ten years ago, I was shocked to find that while there were no kitchen chimneys for cookstove smoke, no telephone lines, and very limited electric service connecting indigenous villages, there was excellent cell phone service in a jungle a dozen miles from paved roads. Yet this decade later, a wealthy neighborhood nearby on Long Island's South Shore still lacks reliable cell service.

Only the brave dare forecast ten years ahead the equal of the Dick Tracy wrist-TV, SONY Walkman, iPad, or similar personal device. So who is brave enough to pick the next disruptive equivalent of the steam engine, telegraph, vulcanized rubber, AM radio, penicillin, nuclear bomb, jet airliner, transistor, organ transplant, or Hubble telescope? We shouldn't be surprised if it comes from a Third World country, as an accident, or as by-product of research for something quite unrelated. This may be the ideal time to create a dozen new thinkshops like Menlo Park, Bell Labs, or Xerox PARC.

Triangle Coalition

(continued from page 28)

As an example, if Florida sticks to business as usual, it could spend $780 million implementing the Common Core. Under the bare bones approach, the tab could be as little as $183 million. A blended approach of the two could amount to about $318 million.

"Spending reasonable sums to ensure that America's schools and students successfully attain high standards is a worthy investment," said Fordham Institute President Chester E. Finn, Jr. "That doesn't mean implementing the Common Core will break the bank—assuming states and districts are flexible and forward-thinking about how they spend."

Find the full report of *Putting a Price Tag on the Common Core: How Much Will Smart Implementation Cost?* online at <http://www.edexcellence.net/publications/putting-a-price-tag-on-the-common-core.html>.

RESOURCES

(continued from page 24)

crosize nuclear plants, using buildings for multiple uses, growing food in vertical gardens (*à la* Dickson Despommier), and recycling materials locally with wind power.

Frederick Kaufman and Maggie Kurth-Baker, "Fix the Food Equation . . . By Making Better Seeds," pp. 49-51: We will need to develop seeds that can grow in saltier soil and resist drought, floods, heat, frost, and insects. For wheat this means planting seeds from only the fields which have yielded the best harvests. For rice it means breeding with the weeds growing alongside the rice plants (because they are genetically related). Meat, corn, and biofuels will need to be terminated, because they require too much in terms of pesticides, fertilizer, and water.

Elizabeth Royte, "See the System Whole," pp. 52-53: Though the 366 quintillion gallons of water on Earth are not expected to change, their distribution on Earth will. While sea level rises from melting ice caps, greater evaporation from a warming climate will cause the water level of inland waterways to decline – to the point that Hoover Dam's ability to generate electricity could be jeopardized by 2024. Some means off adapting will be "hard" –in the form of basins to contain floodwater and walls to protect against it – while others will be "soft" – in the form of more efficient water use and reuse. More problematic are ways to move water from where there is a surplus to where there is a deficit – "in 230-foot-long fabric tubes connected by the world's strongest zipper"? Not mentioned is whether the "cold trap" in the upper atmosphere that freezes out water vapor ceases to be cold enough to do this. (With a molecular weight less than that of air, water vapor could thus escape from Earth.)

Damon Tabor, "And If All Else Fails," pp. 54-56: As effects of climate change become more severe, people will be willing to take greater risks to deal with them. Among the proposals are irrigating Australia and the Sahara with water desalinated by nuclear plants to support the growth of trees planted there, seeding the ocean with iron to support phytoplankton growth, damming the Bering Sea to keep the Arctic cold, and installing sunshades at the L1 Lagrangian point.

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Can Economics Justify Space Exploration?

Viraj Pandya is an undergraduate at Rutgers University. He is a very enterprising undergraduate, who set up a weekly series of lectures on astronomical and cosmological topics, presented by the Rutgers Astronomical Society, which he, in effect, founded. He even secured funding to provide free pizza and soda to those who attended, many of them fellow students, who came to hear special lectures given by their professors.

On 19 April 2012 Pandya gave the lecture himself – on "The Great Exploratory Tragedy of Our Time: *Human* Space Exploration." When he surveyed the history of space exploration, he was disappointed to note that the motivation for it was political – a race between the United States and the former Soviet Union motivated by the Cold War between these two then-superpowers. Pandya lamented this because he sees science and scientific exploration as an enterprise shared by all humans, not just those of certain nations.

The way Pandya saw around the political motivation for space exploration was economic motivation. But, alas, he recognized that "There is no economic argument in favor of space exploration yet!" "Until there is an 'economic theory of space exploration' which can prove that (human) space exploration is important," he concluded, "nationalistic and competitive space exploration will reign supreme."

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 lead story in the 18 March 2012 issue of *The Times* of Trenton (NJ) described instances of converting agricultural fields to solar farms. While the article focused on objections to the visual impact, it also suggested a land use conflict similar to that between growing corn for food and biofuel. Solar farms emplaced on arable land reduce the amount of arable land available to grow food, while solar farms emplaced on non-arable land or rooftops do not. Should converting arable land to solar farms be banned?

Wagner

(continued from page 8)

Wagner's answer to the final question was that Advanced Placement (AP) is not a good indicator of anything, and he said that even AP knows that – that's why they are revising their science and history courses.

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H5N1 papers

(continued from page 32)

search so that bioterrorists reading them could not replicate their efforts to make an H5N1 virus that was transmissible between ferrets (the mammal which, for purpose of transmission of viruses, is closest to humans) – Kawaoka's had been submitted to *Nature*, Fouchier's to *Science*. Fouchier, Kawaoka, and a host of other researchers working with H5N1 published the announcement of a 60-day moratorium on their research in the 27 January 2012 issue of *Science*.

The WHO meeting that recommended full publication of both Fouchier and Kawaoka papers was held in February, but the recommendation for full publication was qualified that the publication should occur only after the 60-day moratorium, with the intervening time to be used to increase "public awareness." One reason for full publication was so that such publication would inform public health authorities how the H5N1 virus could be engineered to endanger humans and thus enable them to know what kind of countermeasures to take. The only alternative would be to set up a network of people who would need this information and transmit it to them separately from the open science publication system. The difficulty of doing this would later play an important role.

Fouchier's talk about his research to the American Society for Microbiology in March seems to have been the beginning of a turning point. Fouchier revealed what he had done: Swabbing the noses of four ferrets with the mutant virus infected three of them. Swabbing the noses of two uninfected ferrets with the virus isolated from one infected ferret caused transmission of the infection to two ferrets in a neighboring cage. The mutant H5N1 virus did not transmit among ferrets as effectively as influenza viruses that affect humans, and no ferrets died from the H5N1 mutations. Anthony Fauci, head of NIAID, who had previously opposed full publication of Fouchier's work (because the governmental perspective as well as the scientific perspective need to be considered) was grateful for this clarification provided by Fouchier and urged that it be incorporated into the manuscript and resubmitted to the NSABB.

Submission of revised papers from both Kawaoka and Fouchier to the NSABB elicited unanimous approval to publish Kawaoka's paper in full and a 12-6 vote to do the same for Fouchier's (one no vote came because Kawaoka had taken steps to make his manipulated virus less virulent while Fouchier had not). A further factor in this decision was the recognition that there was no effective way short of full publication to release the full information to all who needed it.

One by-product of dealing with Fouchier's and Kawaoka's research was a four-page *U.S. Government Policy for Oversight of Life Science Dual Use Research of Concern*, which calls for universities to identify and monitor sensitive research involving 15 "high consequence" pathogens (including H5N1) in the context of a checklist of seven criteria and for federal agencies to "screen funding proposals for 'dual use research of concern' [DURC]" on the same basis. Funder and researcher might negotiate changes to proposals so marked, and agencies can "request voluntary redaction of the research publications or communications."

All was now clear for publication of Kawaoka's paper, which was published in the 2 May 2012 issue of *Nature*. Kawaoka and Fouchier had hoped that both their papers would be published at the same time, but there was still one more hurdle for Fouchier to overcome. While he had earlier voiced the feeling that he had "nipped the debate [about mutated H5N1 research] in the bud" in his native Netherlands through his communication about it to the Dutch media, he apparently hadn't reckoned that some members of the Dutch House of Representatives would prompt the Dutch government to consider that publication of his research in an American journal constituted export of sensitive technology, even though it had been funded by an American agency. Because appealing this decision through Dutch courts would have delayed publication of his work even further, Fouchier applied for an export license on 24 April and received it three days later.

Publication of Fouchier's work in the 22 June 2012 issue of *Science* showed the difficulty with which the H5N1 virus was made transmissible between ferrets. After inserting three mutations showed no change in transmissiveness, the H5N1 virus, with these three mutations, was subjected to "passaging" – inoculating an $(n+1)^{th}$ uninfected ferret with a nasal sample from an n^{th} infected ferret – and it was found that 10 passagings were needed. (Kawaoka's approach was to stitch the viral protein hemagglutinin from H5N1 onto the 2009-2010 pandemic H1N1 virus.) All of Fouchier's viruses contained more than nine mutations, five of which were shared by all, three of them being the mutations directly inserted by the researchers before the passagings. One of Fouchier's five common mutations was located at the same receptor binding site as one of Kawaoka's four mutations.

Meanwhile, the moratorium set to expire in March remained in effect, pending implementation of the *Policy for Oversight of Life Science Dual Use Research of Concern*.

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H5N1 papers published

The Infusion Tip in our Winter 2012 issue asked students to voice whether papers describing the genetic engineering of H5N1 avian flu virus to make it transmissible between mammals should be published, as the World Health Organization (WHO) had recommended. Such an Infusion Tip based on real life occurrences is a good way to help students appreciate the role of science in their lives, but only so long as the issue it raises remains unresolved.

This is one story that has now been resolved, although its resolution leaves behind the issue of screening future research for concerns about dual use. The story is chronicled by *Science* magazine, where one of the two papers in question was published, by a group headed by Ron Fouchier of Erasmus Medical College, Rotterdam, on 22 June 2012. Initially, it wasn't supposed to happen this way. Fouchier and Yoshihiro Kawaoka of the University of Wisconsin (Madison) and the University of Tokyo, who had both received funding for their research from the U.S. National Institute of Allergy and Infectious Diseases (NIAID), had agreed to a request from the U.S. National Science Advisory Board for Biosecurity (NSABB) to "omit key details" from the papers describing their re-

(continued on page 31)

IN THIS ISSUE