TEACHERS CLEARINGHOUSE
FOR SCIENCE AND SOCIETY EDUCATION
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Earth's Future according to *Gaia*

As James Lovelock tells it in *The Vanishing Face of Gaia: A Final Warning* (Basic Books, New York, 2009), the concept of Gaia as a "self-regulating Earth with the community of living organisms in control" (p. 159) was born as a hypothesis ("If the atmosphere of the Earth is a biological contrivance. . . .") without being named in a 1968 paper in the *Proceedings of the American Astronomical Association*. The evidence leading to the Gaia hypothesis was evidence of chemical disequilibrium of planetary atmospheres as an indicator of life. With their preponderance of carbon dioxide, the atmospheres of Mars and Venus betrayed no such disequilibrium, but the constant proportion of oxygen and methane in Earth's atmosphere indicated that something had to be continually infusing these gases. ". . . the Gaia hypothesis . . . stated that the Earth's atmospheric composition is kept at a dynamically steady state by the presence of life; moreover, if organisms could affect atmospheric composition

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From Earth to *Eaarth*

In the Preface of his latest book, *Eaarth: Making a Life on a Tough New Planet* (Holt, New York, 2010), Bill McKibben writes that "The first point of this book is simple: global warming is . . . *no longer a threat at all*. It's our reality. We've changed the planet, changed it in large and fundamental ways." Concerned that "the reality described in this book, and increasingly evident in the world around us, will be for some an excuse to give up," McKibben argues for "increased engagement . . . to keep climate change from getting more powerfully out of control." Although "we've lost [the] fight to preserve the world we were born into" and must therefore adapt to a changed world, "if we don't stop pouring more carbon into the atmosphere, the temperature will simply keep rising, past the point where *any* kind of adaptation will prove impossible." (p. xv)

McKibben observes that the world of the first ten thousand years of human history has offered predictable climate that fostered our agriculture and protected us from

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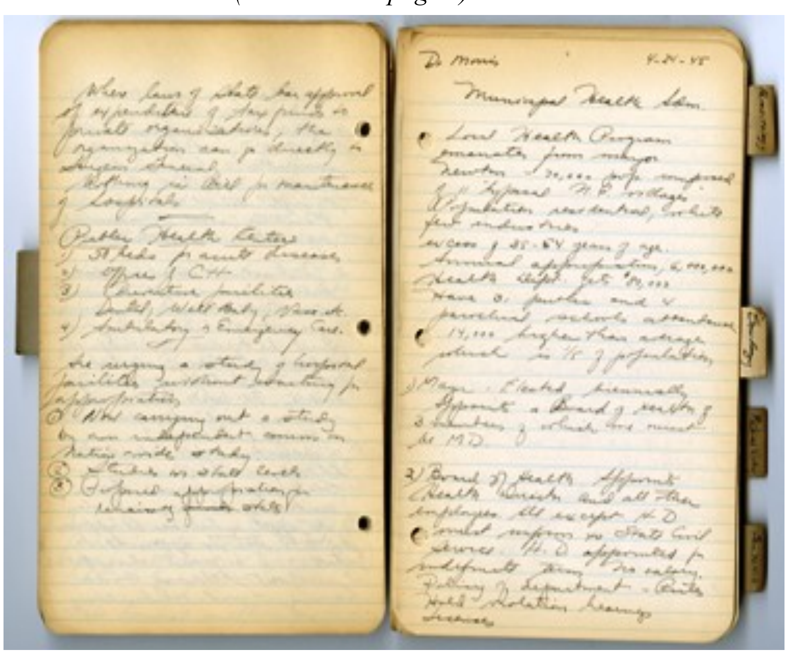

Harvard Public Health Exhibit Features Jarcho Notebook

The Harvard School of Public Health has mounted an exhibit, "Dissolving Boundaries: Extending the Reach of Medicine and Public Health," to commemorate the several decades following the end of World War II, when physicians and public health leaders began to grapple with such central issues as the organization and delivery of medical care, maternal and child health, poverty, end of life care, smoking and alcoholism, obesity, and, increasingly, social justice and the assurance of health as a basic human right worldwide. One of the public health students during this period was Clearinghouse Cofounder and Editor Emerita Irma Jarcho, and one of her notebooks is a featured part of this exhibit.

An EDITORIAL: Views on STEM Ed and Scientific Literacy

The five reports about STEM education that delayed publication of our Fall 2010 issue focused heavily on the importance of innovation as a key to our nation's future. The issues of STEM education and innovation are key themes for coverage in this *Newsletter*, and our affiliation with the Triangle Coalition for Science and Technology Education has called our attention to two more important documents, to which we would like to call special attention in this issue.

The first of these is a 178-page report, *Refueling the U.S. Innovation Economy: Fresh Approaches to STEM Education*, written by Information Technology and Innovation Foundation (ITIF) Founder and President Robert D. Atkinson and Merrilea Mayo. The ideas offered by Atkinson and Mayo are often at variance with those in the reports covered in our Fall 2010 issue; but, whether you agree with them or not, we felt that they were sufficiently worthy of your consideration to provide coverage of them in this issue. This coverage, which begins on page 3, is admittedly much longer than a usual article in this *Newsletter*, but we couldn't find a way to condense it and still do justice to the wide variety of points made in this ITIF report.

The other document is an anthology, *Science and the Educated Person: A Core Component of Liberal Education*, edited by Jerrold Meinwald and John G. Hildebrand and published by the American Academy of Arts and Sciences, which is reviewed in this issue. There you can read about the views of some of the contributors, many of whom have been covered in previous issues of this *Newsletter*, about the importance of a scientifically literate citizenry, how scientific literacy is being achieved, and how it can best be achieved.

There's a lot more related to the role of science in society in this admittedly large issue, and we hope you will check all of it out, but we especially wanted to call our coverage of these two particular documents to your attention.

\- John L. Roeder

INSIDE THIS ISSUE

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.

Collaboration: the key to Innovation

Innovation was the theme of our Fall 2010 issue, and the continuation of its importance in President Obama's State of the Union Address, which embraced the PCAST recommendation to prepare 100,000 new STEM teachers over the next decade, warrants its further exploration.

Four years ago Keith Sawyer addressed this subject in a book, *Group Genius: The Creative Power of Collaboration* (Basic Books, New York, 2007), where he developed the thesis that innovation is a group process, not the work of isolated individuals. "Collaboration drives creativity because innovation always emerges from a series of sparks – never a single flash of insight," he writes (p. 7) and then goes on to elaborate in "seven key characteristics of effective creative teams":

1) "Innovation emerges over time."
2) "Successful collaborative teams practice deep listening." ["Most people spend too much time planning their own actions and not enough time listening and observing others."]
3) "Team members build on their collaborators' ideas."
4) "Only afterwards does the meaning of each idea become clear."
5) "Surprising questions emerge." [". . . most creative groups are good at finding new problems rather than simply solving old ones."]
6) "Innovation is inefficient." [". . . all we remember is the chain of good ideas that made it into the innovation; we don't notice the many dead ends."]
7) "Innovation emerges from the bottom up." [". . . the most innovative teams are those that can restructure themselves . . . [to] start with the details and . . . work up to the big picture," while "Most business executives like to start with the big picture and then work out the details."]

Sawyer then goes on to make several related observations, many of them based on his own experience participating in jazz and theatrical improv groups:

". . . innovation can't be planned, it can't be predicted; it has to be allowed to emerge." (p. 25)

". . . when people improvise together, they develop innovative responses to unexpected events even though no

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ITIF: Reform STEM Education to Refuel Innovation

As seen in our coverage of its report, *The Atlantic Century: Benchmarking EU and U.S. Innovation and Competitiveness*, in our Fall 2010 issue, the Information Technology and Innovation Foundation (ITIF) has an abiding interest in maintaining the United States at the forefront of technological innovation. Now ITIF Founder and President Robert D. Atkinson is joined by Merrilea Mayo in publication of a 178-page report, *Refueling the U.S. Innovation Economy: Fresh Approaches to STEM Education*. They give three reasons to spur innovation: the economy, international competitiveness, and meeting societal and individual needs. Elaborating on the first of these, they cite that technological innovation is responsible for 75% of U.S. economic growth since World War II and 55% of U.S. productivity growth from 1959 to 2005, has yielded a 40% societal rate of return from investment in academic research, and has replaced low-paying jobs with high-paying jobs. Among the meeting of societal and individual needs are health care, education, transportation, environmental protection, and agriculture.

"For over a half century, science-based innovation has powered America's economy, creating good jobs, a high standard of living, and U.S. economic and political leadership. Yet, our nation's global share of activity in STEM-focused industries is in decline, jeopardizing our status as the world's leader in innovation. Moreover, there is clear evidence that the United States is consistently not able to produce enough of its own STEM workers in key fields," the report begins. "While increasing the quantity and quality of U.S. STEM graduates will not by itself solve the problem of declining U.S. innovation-based competitiveness, it is an important component of a larger national innovation strategy. Consequently, there is increasing concern over how to give more American students stronger STEM skills and get them into STEM jobs." (p. 6)

One of the first things that Atkinson and Mayo do is to inventory the history of college degrees awarded in the U.S., in both STEM and non-STEM fields. While they find that there are not enough native-born Americans to fill all U.S. STEM jobs, they note that a majority of the 18% of the STEM workforce who are foreign born are permanent residents. (This contrasts with only 11% of the general U.S. workforce that is foreign born.) More-

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Gaia

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then maybe they could regulate the climate of the Earth to keep it favorable for life." (p. 163)

Although Richard Dawkins demonstrated the impossibility of this hypothesis in *The Extended Phenotype* (Freeman, San Francisco, 1982), Lovelock's belief that geochemistry alone could not regulate the composition of Earth's atmosphere persisted. "Then [he] wondered, what if the whole system of life and its environment tightly coupled [rather than life alone] did the job?" (pp. 168-170) This was the basis for a revised Gaia hypothesis, which Lovelock has now promoted to the status of a theory, for which he then states ten predictions. Lovelock writes that, in turn, over a thousand scientists signed The Amsterdam Declaration in 2001, that "The Earth System behaves as a single, self-regulating system comprised of physical, chemical, biological, and human components," but that he recognized that Gaia also required recognition that "the goal of self-regulation is the maintenance of habitability." (p. 179)

Whether his ten predictions of Gaia theory, as Lovelock calls it, are unique to that theory can be called into question, but it is nevertheless clear that the theory gives Lovelock a unique perspective in looking at the evolution and future of life on Earth. Of primary concern to Lovelock is the current change in Earth's climate. "The root cause [of climate change]," he writes, "is too many people . . . more than the Earth can carry." (p. 5) ". . . the presence of 7 billion people aiming for first-world comforts is too much. . . ." (p. 63) "No voluntary human act can reduce our numbers fast enough even to slow climate change. Merely by existing, people and their dependent animals are responsible for more than ten times the greenhouse gas emissions of all the airline travel in the world." (p. 5) Later (on p. 71) he writes that with humans and animals responsible for 23% of greenhouse gas emissions, increased to 50% when food production and distribution are thrown in, a 60% reduction in greenhouse gas emissions would be impossible without a reduction in animal life. Barring a realistic way to avoid climate change, Lovelock advocates devising ways to adapt to it, as a person who eventually becomes accepting of an incurable disease.

Even later he describes humans as the infection responsible for this incurable disease. "We became the Earth's infection," he writes, "when we first used fire and tools purposefully. But it was not until about two hundred years ago that the long incubation period ended and the Industrial Revolution began; then the infection of the Earth became irreversible. . . ." (p. 233) "For too long we have seen the Earth as a resource. . . . We are beginning to glimpse the possibility that it may be finite and soon empty, but still we try to make sure that we at least get what we need from the dwindling remainder. . . . Our error is to take more than the Earth renews." (pp. 246-247) Lovelock goes on to note that the present human "infection" of Gaia is only one in a series of catastrophes she has experienced, including bacterial poisoning of the atmosphere with oxygen, meteoric impacts, and volcanic eruptions, and she has withstood every one. This results from the rules by which the universe runs, which humans have sought to learn. Paramount among these is the second law of thermodynamics, which will make it more difficult for Gaia to withstand future catastrophes. But "the proximate cause of Gaia's ageing is the ineluctable increase in heat from the sun." (p. 237) In 500 million years, he continues, the radiation from the sun will be 6% greater than now, and the amount of this increase will be sixty times the amount we are presently adding due to extra heat due to greenhouse gas emissions.

Lovelock counsels that ". . . we have to stop pretending that there is any way back to the lush, comfortable, and beautiful Earth we left behind sometime in the twentieth century." (p. 68) But, because he looks at The Earth System as a living organism, his view is that "it is hubris to think that we know how to save the Earth: our planet looks after itself. All that we can do is try to save ourselves." (p. 13) Indeed, we are "not the owners, managers, commisars, or people in charge. The Earth has not evolved solely for our benefit, and any changes we make to it are at our own risk. . . . We are creatures of Darwinian evolution, a transient species with a limited lifespan, as were all our numerous distant ancestors." (p. 9)

"But," he continues, "we are also intelligent, social animals with the possibility of evolving to become a wiser and more intelligent animal, one that has a greater potential as a partner for the rest of life on Earth. Our goal now is to survive and to live in a way that gives evolution beyond us the best chance." (p. 9) "As I see it, our hope lies in the chance that we might evolve into a species that can regulate itself and be a beneficial part of Gaia. . . ." (p. 246) Thus, although we have exercised "our inherited urge to be fruitful and multiply" (p. 240), Lovelock sees our future salvation in regulating ourselves to be a beneficial partner to Gaia, adding that "Gaia needs us." Moreover, "it has taken Gaia 3.5 billion years to evolve an animal that can think and communicate its thoughts"; and should "we become extinct she has little chance of evolving another." (p. 28)

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Rutherford presents Galilean *Dialogue*

Since its review of *Science for All Americans* in its Fall 1989 issue, this *Newsletter* has covered the development of Project 2061, initially under the direction of F. James Rutherford. For his work in developing Project 2061, Harvard Project Physics, and many other facets of science education, Rutherford was the 2011 recipient of the Oersted Medal of the American Association of Physics Teachers (AAPT).

In his response upon receiving the Medal at the Association's meeting in Jacksonville (FL) on 10 January, titled "The Particle Dilemma and High School Physics and Science Literacy," Rutherford took his cue from Galileo in reporting a *Dialogue Concerning the Two Chief Physics Education Systems* (in Italian, *Dialogo sopra i due massimi sistemi del fisica educazione*). His interlocutors, modeled after Galileo's, were Simplicio, "a physicist from LeConte Hall," the physics building at University of California-Berkeley, where Rutherford is currently affiliated; Salviati ("a science educator said to be a drifter who wandered from schools to universities to government agencies before finally ending up with a full-time job at a scientific society . . . committed to the notion that the chief value of physics in high school has to do with the distinctive contribution it can make to scientific literacy, an outcome to which traditional physics courses, he believes, do not contribute significantly"); and Sagreda ("a transvestite Berkeley activist . . . elected to the Berkeley School Board on the lively slogan 'Learning Trumps Everything Else!'"). A close examination of Rutherford's description of Salviati reveals that Salviati represents Rutherford himself, just as Sagredo in Galileo's *Dialogue Concerning the Two Chief World Systems* is a student with the inclinations of Galileo.

Although Rutherford's *Dialogue* was not as long as Galileo's, it does run 37 pages, more than can fit into an hour lecture, so Rutherford had to present an abbreviated version to his audience. He structured it as did Galileo, in three days, devoted, respectively, to the value of high school physics for students, society, and physics itself. In his arguments on behalf of high school physics for students, Simplicio defends the exalted position that physics occupies in the high school physics curriculum; Salviati counters that this poses a problem for the attainment of scientific literacy for all. Simplicio argues that students need to study the traditional physics course to learn exciting new developments in physics, such as the search for the Higgs boson, which Salviati says "illustrates what I call The Particle Enigma." Salviati also characterizes Simplicio's argument that physics should be studied because it is "the fundamental science" as "The Granddaddy Conceit." And Salviati calls Simplicio's call to study high school physics in order to learn to think like physicists "The Brain-Power Pitch." Sagreda observes that "students take history to learn about our past, not to learn to think like historians" and "take literature to learn how people behave in different situations, not to learn to think like novelists." And Salviati adds that physicists think alike only when they are doing physics, not in their actions as private citizens. Salviati calls Simplicio's last argument related to high school physics for students – that it enhances students' acceptance at a university – the "Bitter Medicine Bribe."

Sagreda summarizes Salviati's refutations of Simplicio's arguments on the "first day" as follows:

- Today's physics is out of the reach of most people, including those having had a traditional high school course in physics;
- A senior year course in physics is in no position to improve a student's understanding of the other school sciences;
- There is no evidence that a physics course as ordinarily taught provides students with scientific thinking skills that transfer to ordinary life situations;
- It is unlikely that a 12th grade physics course on a transcript has much influence on college admission. . . .

On the "second day" of Rutherford's *Dialogue*, when the focus is on high school physics for society rather than students, Simplicio argues that the value of physics for society "cannot be doubted," because it enables citizens to participate in scientific decisions as well as enhance their employment opportunities. Salviati calls this the "Value-Added Decoy," maintaining that scientific decisions are made by scientists and that not all scientists agree on issues beyond the boundaries of science. Sagreda interjects by reporting a presentation the previous evening to the Berkeley School Board by Rutherford claiming "that one way to increase the relevance of science to society is to organize instruction *contextually*." Salviati (representing Rutherford in the *Dialogue*) adds "that *contextual* teaching gives us a way to make science teaching socially significant."

With regard to what he calls "The Comparison Distraction," Salviati urges care "about jumping on the 'America's schools and teachers are terrible' bandwagon." "TIMSS focuses mostly on the fourth and eighth grades, and PISA on fifteen-year olds" (before most high school students study physics), he says, also noting that Shanghai scored well on these tests because Shanghai authorities attracted superior students to take

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Galilean *Dialogue*

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the tests and told the students that it was important for China's image. To Salviati, the only meaningful tests are the National Assessment of Educational Progress (NAEP), where he has two worries: "traditional high school physics does not reach enough students, and it does not contribute as it should to science literacy for all students and to the dynamic curriculum that would energize and enrich the learning of all students." In response to Simplicio's request for a definition of "science literacy," Salviati refers him to *Science for All Americans* and the subsequent publications of Project 2061. In his presentation to AAPT, Rutherford cautioned against "crisis addiction" leading to "reform impatience" leading to "panacea proclivity."

The "third day" dialogue, which focused on physics education for physics, dwelt on what Simplicio cited as a shortage of physicists and what Salviati termed the "Species Survival Mandate." Salviati cites data showing an increase in U.S. physics doctorates from 1378 to 1586 between 1998 and 2008 and laments that they are spending a longer time as post-docs. He adds that he has "sundered the notion that the high schools should be responsible for sustaining the physics pipeline and for building public support for physics research – what I think of as Physics Forevermore and More."

The first three "days" of dialogue are followed by a "fourth day," in which the "author," Rutherford is introduced as the Oersted Medal Award Recipient (OMAR) to field questions from a very interesting group of questioners. To a question from defeated California gubernatorial candidate Meg Whitman about "useful" education, he replies that "general education, as I construe it, is not vocational education . . . but it is the best bet we have for producing graduates who are ready to lead interesting and useful lives." To Physics Professor S. James Gates, who co-chaired the PCAST Working Group that prepared *Prepare and Inspire: K-012 Education in Science, Technology, Engineering, and Math (STEM) for America's Future* (reported in our Fall 2010 issue) and asks where science fits into the "general education" scenario, OMAR responds that he is writing a response to the PCAST report which will be posted on his website <www.scienceeducationencore.org> and laments that only four of the 80 people responsible for that report are school teachers. He also goes on to iterate that science literacy is *not*

- having acquired a mish-mash of scientific facts, laws, and theories, since science literacy requires coherence, a view that sees science as a dynamic human enterprise;
- having become a "little scientist" . . . .;
- having completed some number of traditional science and math courses. There is little evidence of interconnectedness among science courses or between science and math courses. . . .

But it *is*

- being aware that over the course of human history, people have developed many interconnected and validated ideas about the physical biological, psychological, and social worlds . . . that have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environment. . . .;
- being familiar with the natural world and respecting its unity. . . .;
- seeing the relevance of science in various contexts such as engineering, environment, energy, health, history, and themes such as systems and scale.

When Galileo accuses OMAR of setting up Salviati as his mouthpiece, "giving him strong arguments for putting down the traditional high school physics course defended weakly by Simplicio," OMAR rightfully retorts that "Salviati was your mouthpiece and your *Dialogue* is anything but balanced." And in response to U.S. Secretary of Education Arne Duncan's Twitter, OMAR responds that "I do not believe we are in or ought to be in 'a race to the top.' . . . If anything, a balanced general education is what we ought to be as good at or better than any other country, but that is being undermined by a race to the top based almost entirely on the 'objective' test mania." OMAR then continues, "In this country we are fully capable of setting our K-12 learning goals and organizing ourselves to achieve them . . . if we stop the current fashion of denigrating our schools and teachers, but reach out to help them to improve themselves and the system." He adds that American schools are "not responsible for Vietnam or Iraq, for the recessions we have had since the end of WWII, for the large influx of immigrants from every corner of the world, for the rising level of poverty among children, for state and federal budget deficits – but they are affected by those and many other situations for which they have no responsibility."

Finally, in response to a question from Dante who has sensed OMAR's equating high school science education to Purgatory, OMAR replies that "science education is situated between abject failure and dreamy perfection." Reform can keep it from "the everlasting hopelessness of the Inferno . . . but we cannot hope for Paradise, which is to say for a perfect system of education. To his AAPT audience Rutherford recommended tenure reform and preparing fewer science teachers but with a seven-year

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Fifth Physics Education Symposium Addresses Science Education Policy

"Democracy requires an educated and engaged citizenry" were the opening words of Moderator Noah Finkelstein at the Fifth Annual Symposium on Physics Education on 11 January 2011 at the meeting of the American Association of Physics Teachers (AAPT) in Jacksonville. This Symposium has become a regular feature of the winter AAPT meeting, and this year's Symposium was devoted to "Education Policy: Having an Impact, Improving the Landscape." Discussing this topic were Michael Lach, Special Assistant for Science, Technology, Engineering, and Mathematics Education, U.S. Department of Education, and Stephen Pruitt, Vice President, Content, Research and Development, Achieve, Inc.

Lach began by stating that President Obama has demonstrated an interest in science and science education. He acknowledged what has already been pointed out in the Fall 2005 issue of this *Newsletter*, that there has been a slew of reports of what to do about it – a slide showed a sequence of ten, from *A Nation at Risk* to *Rising Above the Gathering Storm*. "We don't need more reports," Lach said. "We need action."

He then went on to say what action he'd like to see:

1. "All hands on deck" – we *all* need to be engaged in solving the problem. Lach described the problem in terms of what happened to the 4,013,000 entering ninth grade in 2001. Only 2,799,000 graduated from high school four years later, and of these only 1,170,000 entered college. Only 278,000 declared STEM majors and of these only 167,000 are expected to graduate with a STEM degree.

2. "STEM education reform is part of education reform in general." Here Lach saw four important elements: 1) standards and assessments, 2) effective educators, 3) data systems, and 4) reversal of low-performing schools. These, he pointed out, are codified in *A Blueprint for Reform* to reauthorize ESEA (the Elementary and Secondary Education Act), and he contrasted the *Blueprint* with the present version of ESEA, "No Child Left Behind" (NCLB) as follows:

No Child Left Behind	*Blueprint for Reform*
Lowered bar	Raised bar
Too prescriptive	More flexible
Too punitive	Recognizing of success
Narrowed curriculum	Well-rounded education

Lach added that "NCLB led a 'Race to the Bottom' in state standards."

3. "The nature of STEM demands specialized strategies." As an example, Lach noted that math education is something regarded as requiring external assistance, while language arts are not. Moreover, lesson quality is associated with adherence to district-designated materials more in math and science than in language arts.

4. "Motivation and inspiration matter." Lach recognized that kids start out interested in science but lose their interest; therefore, we need to keep them interested. He also lamented that superintendents and principals don't share the U.S. Department of Education's concern about STEM education and that high school leaders aren't physics leaders.

Lach concluded his presentation by applauding the Physics Education Research being done and hoping for common standards in science to match those in math and language arts. But, he said, this will not happen if the math standards don't "work," by which he meant improvement in the heretofore static TIMSS (Trends In Math and Science Study) scores. In spite of NCTM (National Council of Teachers in Mathematics) standards, math teaching has not changed, Lach lamented. In effect, these standards have not been implemented.

Speaking to a national perspective on science standards, Pruitt began by iterating what has already been reported in the Fall 2010 issue of this *Newsletter*, that the National Research Council released a draft *New Framework for Science Education* in 2010, reflecting new developments in science and how students learn it. Pruitt's organization, Achieve, a non-partisan non-profit education organization that developed the Common State Standards in Mathematics and Language Arts, is then to translate the finalized *Framework* into the Next Generation Science Standards, which will focus on core knowledge and skills rather than content. All 50 states will have the opportunity for input into this process.

Underlying the *Framework* are the principles that 1) children are born investigators; 2) understanding develops over time; and 3) science is more than a body of knowledge. Pruitt said that the Standards would intersect core ideas, cross-cutting ideas, and STEM topics in the context of practices for science classrooms. In developing them, he said that Achieve would employ writing teams, critical stakeholder teams, strategic advisory

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Gaia

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Lovelock observes that ". . . if we can evolve to become an integrated intelligence with Gaia, then together we could survive longer." (p. 97) But implementing the future Lovelock seems to envision is not what many environmentally-minded people on Earth today have in mind. He is critical of the work of the Intergovernmental Panel on Climate Change, because their work is based on climate modeling and depends on political consensus rather than observation. And he eschews wind and solar photovoltaic energy as a scam perpetrated by the purveyors of the required equipment, because these sources are intermittent, preferring solar thermal electricity and nuclear energy instead. In keeping with his Gaia theory, Lovelock writes that "we have to see Earth as something able to resist adverse change until the going becomes too tough and then, like a living thing, escape rapidly to a safe haven. . . Now our interventions are too great to resist and the Earth system seems to be giving up its struggle to flee to a safe place, a hot state with a stable climate, one that it has visited many times before." (p. 180) Indeed, in his book he writes of "global heating," not "global warming," and cautions that while "We are strong and adaptable animals and can certainly make a new life on the hotter Earth . . . there will be only a fraction of inhabitable land left compared with that available in 1800. . . ." Thus "there will be a great clamor from climate refugees seeking a safe haven in those few parts where the climate is tolerable and food is available." (p. 248) He likens this situation to admitting people to a lifeboat – load it too full and it will sink.

Physics Ed Symposium

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teams, comprehensive feedback loops, as well as state involvements. Still to be resolved are whether to write standards for specific grades or for bands of grades, whether there should be integrated or disciplinary courses in middle school, and how to relate science standards to math standards. He said that Achieve had studied science standards from ten other countries, including Canada (Ontario), Chinese Taipei, England, France, Hong Kong, Hungary, Singapore, and South Korea. They found that seven of the ten countries taught general science courses through grade nine. Shortcomings of the current science standards would be addressed by adding the following new features in the new standards: 1) incorporation of math; 2) evidence-based inquiry; 3) model building; 4) engineering design; 5) concepts in modern biology; and 6) interdisciplinary connections.

Karraker celebrates life and work of great-grandfather

by John L. Roeder

"A Profile of the Father of Modern Plastics: Leo H. Baekeland" was presented to the Physics Club of New York at New York University on 11 March 2011 by Baekeland's great-grandson, Hugh Karraker.

According to a film Karraker made about his great-grandfather, Baekeland was born in 1863 in Ghent (Belgium), where he entered the university at age 17 and emerged with a doctorate four years later. After that, according to Karraker's subsequent presentation, Baekeland, inspired by a biography of Benjamin Franklin, decided to seek his fortune in the United States.

Baekeland began his career as a photochemist, Karraker told us; but, out on his own as a consultant, he was not successful. However, Baekeland's Nepera Chemical Company succeeded in cornering the market on Velox photographic developing paper, and Baekeland later sold his company to George Eastman for $750,000.

After studying electrochemistry and working for Hooker Chemical, Baekeland turned to the chemicals – phenol and formaldehyde – that make Bakelite – the first completely synthetic plastic – in his "Bakelizer." Among its many uses, Bakelite replaced celluloid as the constituent of billiard balls. Baekeland established the Bakelite Corporation, with facilities to manufacture Bakelite in Perth Amboy and later in Bound Brook, NJ, which he subsequently sold to Union Carbide, now a subsidiary of Dow.

Karraker recounted how his mother, Céline Baekeland Karraker, read 62 of Baekeland's diaries but never wrote her planned book about them. In establishing the Baekeland Project to celebrate the life and work of his great-grandfather, Karraker is taking up the mantle first assumed by his mother.

Karraker concluded his presentation by showing a film produced by Bakelite Corporation to extol the plastic's many uses. When I asked Karraker how many of these uses are still being met by Bakelite, he responded "All of them!" Bakelite, he went on to clarify, is known today as phenolic resin, and it is still being used for laminates, finishes, and adhesives in thousands of applications.

New Tech Devices: More Complex, but Fewer in Number

by John D. White, Technology Correspondent

"Convergence" may become the buzzword for the twenty-teens. If so, it replaces the previous decade's "digital." At the end of 2010, SONY phased out a 1979 product, the Walkman. Other "analog" sources of sound have also receded, whether on vinyl record, AM radio, or wired telephones. Dial tones and busy signals are giving way to cell phones and voice mail. Soon "digital" will be *assumed* unless "analog" is stated. In a similar change-over, we expect timepieces to be electric-powered and multi-function devices, unless one specifies wind-up clocks or watches. When 2011's newborns enter school, they will know as little about audiotape cassettes as we do about Edison's wax cylinder phonograph records. Their parents will remember the Walkman as a quaint but typical single-purpose device of the 20th century.

For decades, science and technology classes have relied on rather simple equipment such as the Petri dish, triple-beam balance, telescope, signal generator, Bunsen burner, VOM multi-tester, and oscilloscope. Some of these can serve multiple functions, albeit within a narrow range, but they have migrated toward the back of the storage closet as classes explore subatomic particles or DNA sequencing. Instead of large pieces of dedicated equipment, the next generation employs small, inexpensive multi-purpose units to perform diversified tasks while needing minimum setup. Sensors, transducers, or distant transponders convey data for processing by a cheap central computer more powerful than those used by an entire Apollo moon mission.

Complexity on a gigantic scale has accelerated in radio astronomy. The first detector was Karl Jansky's 1931 30-meter dipole/reflector "merry-go-round" at Bell Labs. Expanding the field was Britain's Jodrell Bank and Lovell receivers, and onto the monster at Arecibo, Puerto Rico. After more huge dishes were built, some were linked so that the effective diameter grew to thousands of miles, connecting at times Effelsberg, Germany, to Green Bank, West Virginia, to the Very Large Array in New Mexico, plus Arizona's Kitt Peak and Mt. Graham, and even Mauna Kea, Hawaii. Adding Australia's networked dishes and others under construction will allow space observations from a virtual radio telescope equal in diameter to the Earth itself. In 2009 China began construction of the 500-meter diameter F.A.S.T. radio dish in Guizhou, which may join the linked arrays when completed in 2013. Its surface area will equal 30 football fields.

In 1983, Lotus 123 revolutionized software design by connecting three programs with a shared interface: spreadsheet, graphing, and database. Some early "geeks" even used Lotus with a printer to replace a typewriter. Within a decade word-processors changed from desk-sized Wangs to portable Kaypro computers. The ever-shrinking computers not only could string words together and print them, but perform a growing host of tasks that included filing, research, desktop publishing, worldwide communications, and games. Vendors of programs soon competed with their rivals by adding extra capabilities in order to sell often-updated versions. The sales strategy pushed newer editions to existing customers, as well as urging replacement by users of competing programs. Many of these offerings, however, loaded their increased functions simultaneously at startup whether needed or not, leading to complaints of "feature bloat." The heavier demands on old hardware's brainpower slowed and often crashed the whole computer. Instead of supplying smaller, narrow-focused and faster programs, the sellers persisted in devising costly, herniated suites while they waited for hardware capacity to catch up. *Moore's Law* since 1965 had predicted a *doubling* of computer power every year until 2015, although that timeline was later stretched from 12 to 18 months. Thus, time was on the side of those who favored complexity over speedier, tightly-coded, elegant software design.

Hints of oncoming multifunctionality appeared throughout the 20th century. Here are four examples of somewhat slower transition in that era: (1) Horseless carriages first merely hauled passengers in the open air, but through the decades they added all-weather enclosures, heating, radios, high-fidelity sound, air conditioning, roof racks, trailer hitches, back seat TV, and GPS. (2) Supermarkets brought under a single roof formerly isolated greengrocers, butchers, bakers, and delicatessens. (3) Pharmacies branched out to stock what once had been variety store merchandise. (4) The windup Victrola phonograph by degrees evolved into a portable boombox which played AM, FM, tape cassettes and compact disks — loudly.

The 21st century technology for consumer goods not only becomes far more complex, but the *rate* of change itself is accelerating. 4G options (fourth-generation), such as those for cell phone networks, reach the market before most people have moved up to 3G. Because prices of new electronic devices drop throughout the model's sales life, the cost of any needed repairs soon exceeds the price of a new item — one with desirable new features. The

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neighborhood radio/TV repair shop has followed blacksmith's and cobbler's shops into near-extinction.

Today's newest communication devices also shrink their "form factor" (once known as "size") while they grow more versatile and powerful. The newest models and functions arrive so soon that customers and even sales staff struggle to learn function names and select the new features they may wish to consider for use beyond the next few months. The obvious 21st century example is the cell (formerly "cellular") phone. Telephoning from one's built-in call list, the dominant function from five years ago, has given way to a multi-function iPhone or its growing flock of challengers. The buyer is swamped with choices. The *basics* now include a camera, alarm clock, photo storage, music player, video display screen, GPS, Tweeting, texting, and games. Medium-price models join last year's upscale hot-sellers in providing a full Web browser. Not only do they come with searching ability and keyboard, but transmute as well into a Wi-Fi transmitter enabling four nearby computers to connect to the Internet. One may add hundreds — update that to tens of *thousands* — of very small, isolated applications free or at small cost. Shoppers in a store in Japan use the phone's built-in camera to scan UPC barcodes, access the Internet to compare prices elsewhere, then use the same phone to check the bank account and complete a purchase, all without presenting a credit card. The simple cell phone of 2000 served its one function fairly well, but no longer exists in the market. One of these multi-function models is the only option now. We have already reached the point that size of human fingers to operate a keyboard and the fixed distance from ear to mouth limit the shrinking of cell phones and pad or tablet devices.

Lower prices, greater power, and that plethora of new applications have accelerated sales of convergent equipment such as laptop computers, smaller and less expensive "netbooks," business-oriented Blackberries and similar devices, smart phones, iPads and competing "tablets," Kindle and Nook book readers containing dozens of book texts, tiny MP3 players with FM that offer not only live broadcasts and stored music, but narrated books and my favorites, podcasts of previous radio programs. I especially like National Public Radio's "Science Friday" (http://www.npr.org/rss/podcast/podcast_detail.php?siteId=13994790), the "The Naked Scientist" series from Cambridge University (http://www.thenakedscientists.com/), and "Ask a Biologist" from Arizona State University (http://askabiologist.asu.edu/explore/watch_listen).

A third generation of book reader devices to arrive soon will add both full color and sound to children's books. As prices decline, before long they may replace the school textbooks which have become so expensive. Can college textbook replacement be far behind? Lively competition exists between the Apple business model that offers vast numbers of carefully monitored downloads that meet tight quality specifications, and makers of other devices powered by Google's Android operating system or Microsoft's mobile operating system. Other e-reader brands mainly sell their own downloaded books for now, while still others both sell downloads and accept anything from other libraries of various file formats. The latter may originate either with commercial developers selling their files or with open-source communities giving away program applications, music, and documents.

Overlapping technologies give rise to confusion about choices when cable and Internet providers serve as conduits for their rivals: streaming services use the Internet to send movies to the computer or television that bypass the commercial offerings of the ISP (basic Internet service provider, which itself may be fiberoptic or cable such as Comcast, Time Warner, Verizon FiOS, and Dish satellite). The ISP may try to sell telephone service as a package with television and Internet access, but also enables the Internet customer to abandon the ISP's costlier telephone part in favor of different Internet-based service. A December 2010 decision by the Federal Communications Commission empowered Skype or other piggy-backed service rivals to operate at full speed ("Internet neutrality") over the Internet nearly free of cost. However, as of this writing, *wireless* telephone service may be subject to greater cost for higher speed, and action for or against this decision may be expected from the FCC hearings in the near future. This example shows how frequency and variety of new introductions of communication and entertainment products mean government regulation often lags well behind the market.

A different type of convergence appears in the vigorous debate between those who define anthropology as a science and those who reject that classification. However, both sides favor one benefit of increased complexity in research: Various disciplines provide tools that aid others pursuing knowledge about human morphology now and long ago in different parts of the world. Rapid progress in many disciplines means that the venerable carbon-14 dating of organic materials can be checked against thermoluminescence dating of ceramics or other inorganic materials from the same dig site. Potassium-argon dating (based on the potassium-to-argon decay rate) measures the age of inorganic materials just older

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How Watson Could Play *Jeopardy!*

The topic of the last "Science on Saturday" at the Princeton Plasma Physics Laboratory (PPPL) for 2011 was well-known to all: "An Overview of DeepQA: How Watson Could Play *Jeopardy!*" Presenting it was David Ferrucci, who has been on the research staff of IBM's Thomas J. Watson Research Center since 1995 and was the Principal Investigator for the Watson/Jeopardy! Project.

Although Watson's defeat of some of *Jeopardy!*'s former champions on television is well-known, Ferrucci reported that Watson was pitted against 55 former *Jeopardy!* champs and defeated 71% of them. One former *Jeopardy!* champ (back in the days of Art Fleming) who was *not* defeated by Watson, was former Assistant Director of the PPPL and currently U.S. Congressman Rush Holt (D-NJ), who introduced Ferrucci.

Holt also used the occasion to make the case for the larger significance of Watson and how it fits into the larger picture during the evolution of International Business Machines (IBM) and its predecessors during their first century of existence – their continued investment in research, which, Holt pointed out, is how they have consistently distinguished themselves. Holt recalled how in the 1950s IBM developed a computer to play Tic-Tac-Toe and learn from its mistakes. Watson, developed to play a game that requires far more thanking than Tic-Tac-Toe, is a descendant of IBM's earlier computers and a keeper of IBM's tradition of investing in research.

Although Watson attracted far more attention than a project like a health diagnoser that would have more immediate value, Holt noted that Watson employs multilayered processes that promise significant promise in many facets of human endeavor, one of which could be medical diagnosis. He also expressed his hope that the public attention attracted by Watson also persuades the public of the value of research (which he notes has seen the rise of digital libraries from Google and the rise of MRI from research on nuclear magnetic moments). He also reminded us that Watson is technology created by humans.

At the outset of presenting the adventures that distinguished the development of Watson, Ferrucci contrasted the developing of a computer to play chess and a computer to play *Jeopardy!* Chess, Ferrucci said, is a game grounded in mathematically-defined rules. (The same could be said for the example of Tic-Tac-Toe cited by Holt.) But *Jeopardy!* requires conversation, Ferrucci went on, and conversation uses words that have meaning only within the context of their use.

Ferrucci pointed out that computers use knowledge formulated in a way that things can be looked up. This, he said, can be done easily in structured situations. But what about *un*structured information? Ferrucci stated that *Jeopardy!* requires technology of question answering with complex language over a broad, open domain, and to do this quickly with high precision and accurate confidence. This is necessary because, in playing *Jeopardy!* a player must sift through all stored knowledge and come up with a response quickly, yet also know the confidence with which that response is accurate. (To win, you need to answer questions, which means pressing the buzzer first; but incorrect answers take away points.)

Watson had to be able to parse the *Jeopardy!* clue, first to understand its syntactic structure, then to interpret it for meaning. One example Ferrucci presented was "he was U.S. President when *Sixty Minutes* first appeared on television." To answer this question, a contestant first needs to know the year *Sixty Minutes* premiered, then be able to go through a list of U.S. Presidents to match the president with the year. (The year was 1968, the president Lyndon Johnson.)

Ferrucci reported that Watson was tried out with 20,000 *Jeopardy!* questions. Natural Language Processing (NLP) was used to analyze as-is text. Sentences in volumes were parsed into syntactic frames, and generalization and statistical aggregation transformed these into semantic frames.

Key words from *Jeopardy!* questions are important for coming up with answers, Ferrucci went on, and the most confident one must be decided on quickly. He said that Watson "trains" by learning from the successes of its algorithms, and location, passage support, popularity, source reliability, and classification were added as considerations. On a graph of precision (% of being first to press the buzzer) *vs*. % of correct answers, Ferrucci showed where *Jeopardy!* champs are located (upwards of 80% precision and centered on 58% correct answers, except for Ken Jennings who is much higher). He then showed where their Q&A system was in 2007 – with a precision of only about 15% (a higher precision lowered the percentage of correct answers). His team bridged this gap by November 2010 – not good enough to beat all human challengers but able to beat most, he said. To reduce the time to come up with an answer, Ferrucci related, they shifted from a UIMA system (which required a two-hour answering time) to UIMA-AS (which reduced answering time to 2-6 seconds).

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1001 Inventions: the Golden Age of Muslim Culture

The Foundation for Science, Technology and Civilisation (FSTC), based in Manchester, UK, created the exhibit "1000 Inventions" in order "to raise awareness of the contributions the Muslim world has made to the building of modern civilization," with sponsorship by the Abdul Latif Mameel Community Initiative. It recently concluded an extended run at the New York Hall of Science.

Exhibit visitors are greeted by a short introductory film, *1001 Inventions and the Library of Secrets*, in which Ben Kingsley portrays a librarian responding to the inquiries of three British students about the impact the Dark Ages made on the modern world. Perceived as "a thousand wasted years, a black hole in history," Kingsley tells them, the Dark Ages "could not have been more poorly named." To buttress his case that they should be called the "Golden Ages," he assumes the persona of Badi' al-Zaman Abn al-'Izz Ismail ibn al-Razzazz al-Jazari, and calls up the ghosts of four fellow contributors to those Golden Ages of the Muslim world, which extended from Spain to India: Ibn al-Haytham, who invented the camera obscura and discovered how the eyes work; Abbas Ibn Firnas, who flew from the top of a hill with a form of glider fitted to his arms; Abul Qasim al-Zawahri, who developed the scalpel and use of catgut in surgery; and Merriam al-Astrulabiya, who learned to make astrolabes from her father, who had been apprenticed to a famous astrolabe maker in Baghdad (though the astrolabe itself originated with Theon of Alexandria in the fourth century). As for Al-Jazari himself, he is credited with converting rotary to linear motion and building an "Elephant clock," which drew from technological advances from all cultures around the world at the time, in his 1206 *Book of Knowledge of Ingenious Mechanical Devices*.

In video presentations, actors portraying some of these personalities as well as others, including Maimonides, then welcome visitors to the seven kiosks which comprise the exhibit proper (and one of them points out that the word "kiosk" also traces back to the Muslim Golden Age). According to the 376-page book which serves as a companion to the exhibit – Salim T. S. al-Hassani, Elizabeth Woodcock, Rabah Saoud (eds), *Muslim Heritage in Our World*(2nd ed.) (FSTC, 2007), which can be purchased online at <www.1001inventions.com> for $59.50 – these kiosks are categoriezed by the successively expanding spheres characterizing human life: home (engineering of small devices), school (all aspects of learning), market (agriculture, industry, and trade), hospital (medicine), town (architecture and urban planning), world (travel and geology), and universe (astronomy). Among additional things learned from the kiosks are the following:

- Al-Battani (Albategnius) measured the mean solar year to be 365 days, 5 hours, 46 minutes, and 24 seconds in the tenth century.
- Lazari Hasan Celebi was the first human to experience rocket-powered flight, with a gunpowder rocket strapped to his back in 17th century Turkey.
- Ibn al-Nafis realized that air mixed with blood through the lungs (rather than in the heart) in the thirteenth century.
- Al-Marasili, in his *Book of Choices in the Treatment of Eye Diseases* developed a needle through which he could suck out cataracts from the eye.
- Muslim pharmacies stocked over 3000 plants used for medical treatment, and hospitals were extension of mosques, some of which still stand today.
- Fatima al-Fihri commissioned building Al-Qarewiyin in Morocco in 841 with an inheritance from her father; it later evolved into the world's first university.
- Al-Khwarizmi's *Al-Jabr wal Muqabalah* was the foundation of algebra.
- Ibn Sina (Avicenna) wrote *The Book of Healing* in the eleventh century on mineralogy and meteorology.

"1001 Inventions" (the number is taken from the mythical "Thousand and One Nights" of the same era) indeed presents us with many important achievements which have had an impact on the modern world, once they became known. The Muslim world did experience Golden Ages while Western Europe experienced its Dark Ages. But what has happened since then? Two recommended resources in past issues address this. Resource #13 in our Fall 2007 issue expresses Pervez Hoodbhoy's concern that the Muslim world has eschewed the science and its technological applications because "The scientific method is alien to traditional, unreformed religious thought." More recently, resource #15 in our Fall 2010 issue expresses concern that religious conservatism in the Muslim world is a hindrance to accepting the theory of evolution.

Watson/*Jeopardy!*

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Ferrucci added that the algorithms that succeed for *Jeopardy!* may not be the most suitable for other fields, and he echoed Holt's earlier comments by observing that the real payoff for Watson is its applicability to other fields such as medical diagnosis, to cope with escalating medical publication since World War II.

Malik describes eliminating bugs in computer chips

"Bugs" in computers are design flaws that creep into computer chips. But, according to Princeton University Professor Sharad Malik in speaking on "Bug-Free Computer Chips: Boole Meets Moore" at the Princeton Plasma Physics Laboratory on 5 February 2011, this should not be surprising, given the complexity of these chips. But, he stressed, it is important to eliminate them prior to mass manufacturing, because the "debugging" is very expensive.

Malik went on to point out that all computing is information processing in some form and that information is provided in the form of a signal – *e.g.*, voltage *vs.* time, written letters, mathematical representation. He added that signals can be analog (an infinite number of points with an infinite number of possible values) or digital (a finite number of points with a finite number of possible values). The former are converted to the latter by sampling.

Malik next pointed out that the basic unit of digital information is the bit – either 0 or 1 (a single-digit binary number) – and that all information can ultimately be translated into bits. For example, the ASCII code represents all conventional symbols by a seven-digit binary number. Thus, Malik observed, all information processing reduces to the manipulation of bits. This, he said, is done with the algebra formulated by George Boole (1815 -1864), the first-named person in the title of his talk. Applied to logic, Boolean algebra assigns a value of 0 to a variable that is false and a value of 1 to a variable to one that is true, and develops logic operations in terms of three operators, NOT, AND, and OR. For example, NOT 1 = 0, a AND b = 1 if and only if a = 1 and b = 1. All operations can be translated to statements in which NOT, AND, and OR operate on bits. Thus, Malik elicited, error -free information processing depends on getting the correct Boolean formula.

Malik went on to note that one seeks to obtain the simplest possible Boolean formula to accomplish a task. In the process of simplification, he said that it is essential to check for equivalence at each stage, by making sure that the correct outcome results for any specific values of variables in the formula. The number of tests of this nature is 2^n, where n is the number of variables in the formula. But because 2^n can become exceedingly large for even moderate values of n, only critical cases are tested. However, Malik noted, this didn't prevent the FDIV bug in 1994, and the recall cost Intel $475 million.

If two Boolean formulas, f_1 and f_2, are equivalent, Malik observed, then the statement $f_1 \neq f_2$ is never true. He continued by stating that Boolean Satisfiability (SAT) asks whether a given formula is ever true and described this as the fundamental problem in computer science. Malik said that this is tractable for a category of problems that require a number of steps equal to a power of the number of variables, n, but *not* for 2^n – *e.g.*, problems that determine maximum values or sorting. Other problems are solved by making a number of checks or tests, and Malik said that determining whether problems that can be solved with the same number of checks as the number of steps in the previously-described category fit into that same category is today's biggest open question in computer science.

Malik then described how SAT Solvers use search trees, which assign possible values of 0 and 1 to variable a, then the same to variable b and to all other subsequent values, as one might do in a diagram illustrating all possible outcomes of the toss of a multiple number of pennies, for which there are 2^n values for n variables. However, he pointed out that portions of the tree shown to be false at early stages could be eliminated from further consideration, thus reducing the number of tests needed. He also observed that this "early pruning of the search tree" is done in solving puzzles like Sudoku. Malik's research group has produced the Princeton Chaff SAT Solver. Although he cautioned that it offers no guarantees, because the worst cases still require 2^n tests, he said it's good enough in practice. He showed how to Google his SAT Solver and stressed the value of open source collaborative research in this regard.

Noting that "Boole Meets Moore" was part of his title, Malik then observed that we can build logic circuits to represent Boolean operators, using just transistors. (AND would be represented by elements in series, and OR by elements in parallel.) After Bardeen, Brattain, and Shockley invented the transistor, he said that Noyce and Kilby combined them into integrated circuits. The time series for the number of transistors per chip is the basis for Moore's law, articulated by Intel's Gordon Moore (born 1922) on the basis of what has been achieved. This began with 8 transistors per chip in 1962 and rose to 65000 by 1974, but the doubling time increased from 12 to 18 months in 1975, Malik noted.

Although Moore's Law is an empirical observation rather than a law of nature, Malik noted that it has given the industry targets to achieve. It can be expressed as 2^t, where t is the number of doubling times. If transistors each process one variable, then computer chips would

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Gmachl describes Quantum Cascade Lasers

Quantum cascade lasers are semiconductor lasers generating mid-infrared light (from 3 to 30 micrometers in wavelength) to detect gases by the amount of absorption of the laser beam. This can happen because vibrational spectra of molecules are in the mid-infrared region, Professor Claire Gmachl of Princeton University said in speaking to the Physics Club of New York on "The World in Infrared: Quantum Cascade Lasers and Applications" at New York University on 21 January 2011. "If we had mid-IR vision, we could 'see' the chemicals in the air," she added.

Detectors of mid-infrared light are very advanced, Gmachl went on, because of their use in night vision devices, but they can't discriminate wavelengths. This must be done by the light sources, the lasers, she said. They are built from the same material used for lasers used the past 50 years in telecommunications.

Semiconductor lasers make light from the de-excitation of electrons across a band gap. To detect a specific trace gas requires making a laser to generate light of frequencies in the spectrum of the gas. Rather than tailor the band gap to do this, Gmachl creates new materials with desired energy levels by choosing the layering of materials by molecular beam epitaxy. An electric field causes the series of potential wells resulting from the layered materials to slope downward as electrons enter the lasing material; and, as successively lower energy levels become available, the electrons emit cascades of light (hence the name, quantum "cascade" lasers).

Quantum cascade lasers were first demonstrated in 1994 and are just now becoming available commercially, usually as "boutique items," made to order for between $2000 and $3000 for a single application, about ten times that for a comprehensive system. (Gmachl said that making 100 lasers costs little more than making one.) These lasers have been used to monitor tropospheric ozone at the Beijing Olympics and smoke from the fish smoking industry in Ghana. Military applications include detecting toxic gases and uranium hexafluoride.

Gmachl also directs a six-university consortium called the Mid-InfraRed Technologies for Health and the Environment (MIRTHE), which has set a goal to develop quantum cascade lasers of better quality at lower price. One important improvement is to reduce the amount of heat these lasers generate. Ultimately they will be a more portable and less expensive technology to do all kinds of infrared spectroscopy.

(*Editor's Note*: According to the 19 January 2011 issue of the *Princeton Alumni Weekly*, Gmachl's was one of two research proposals (of 47 submitted) to be funded by Princeton's Schmidt Fund, which is "intended to encourage work that likely would be deemed too risky for traditional research grants." The $500,000 Schmidt Fund grant will be devoted to investigating the detection of blood glucose by cascade lasers, a noninvasive boon for diabetics, who now need to prick their finger and use testing strips to monitor their blood sugar.)

Infusion Tips

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

1. According to Jordan Lite, "When Facebook Is Your Medical Record," *Miller-McCune*, **3**(6), 18-21 (Nov-Dec 2010), evidence indicates that postings on social networking websites that suggest risky behavior are reflections of actual risky behavior. Evidence also indicates that those suggesting risky behavior on their websites respond to e-mail offering assistance in dealing with it by expressing either surprise or rejection. In the interest of preventive medicine, is it ethical to screen social networking websites for risky behavior and offer intervention to deal with it? Is it cost effective?

2. According to Chris Wood, "Native Environmentalism and the Alberta Oil Boom," *Miller-McCune*, **3**(6), 26-31 (Nov-Dec 2010), Canada's Environmental Assessment Act requires recording "traditional ecological knowledge" (TEK) from Canada's First Nations (native-Canadian communities) "so that it can be used in projecting and mitigating environmental impacts." The major Canadian environmental impact is the drive to extract oil from the Athabasca tar sands of Alberta – not only for the U.S. (Canada is now our largest foreign source of oil) but also for China. The problem incorporating TEK is that it does not always agree with scientifically-based knowledge, and "More dispiriting still to those who believe in the underlying value of traditional knowledge, many of the languages in which is it encoded are disappearing." How can one answer the question posed by Alberta's Assistant Deputy Environment Minister, Bev Yee: "How do we bridge Western science to traditional knowledge?"

AAPT Commemorates Century of Nuclear Physics

Because it was a century ago that Ernest, Lord Rutherford, developed his nuclear model of the atom, the theme of the January 2011 meeting of the American Association of Physics Teachers (AAPT) in Jacksonville was "100 Years of Nuclear Physics." Starting with a session on "Laboratories that Rutherford Would Approve" and ending with a session on "Rutherford: His Life and Legacy," the meeting was marked by many means by which nuclear physics has come to impact our lives.

Speaking on "Experimental Nuclear Physics at an Undergraduate Institution" at that first session, Shelly Lesher of the University of Wisconsin-La Crosse spoke not only of her school's physics majors but also of the 45% of their students in health-related programs, many of which involve nuclear medicine. They also offer courses on the role of nuclear physics in national security and policy. Lesher also pointed out that as nuclear physics plays an increasing role in our society, we need to replace our aging nuclear workforce (of 14,000 in 2003, she said that 7000 are scheduled to retire by 2018).

Although Rutherford didn't use a particle accelerator in his famous investigation of the scattering of gold atoms by alpha particles, Fred Dylla of the American Institute of Physics noted in his plenary on "Ernest Rutherford and the Accelerator" that Rutherford recognized the need for particle accelerators to further research in nuclear physics and specifically recognized that The Louvre in Paris has its own accelerator to analyze its *ojects d'art*.

In his plenary discussing "The State of the Art in Nuclear Power," Kenneth Peddicord of Texas A&M began by noting that one third of the energy sources in the U.S. is transformed to electrical energy, one fifth of which is produced from nuclear sources. This same percentage of nuclear generation of electrical energy holds worldwide, Peddicord went on, and it is currently provided by 440 reactors in 39 countries. But, he added, there are 61 more nuclear plants under construction (2 in the U.S., 23 in China) and 157 more planned. And 53 more countries have expressed an interest in nuclear power. These developments signaled to Peddicord a "nuclear renaissance," though he conceded that it had not yet taken hold in North America.

Reactors presently in use are called "generation II" ("generation I" is reserved for the original research reactors), which Peddicord characterized as follows: each one was designed specifically for its site (except in France, which used standardized designs) and designed with excessive safety margins. This acted to increase costs of the plants, but Peddicord noted that increasing the percentage of U-235 enrichment in the fuel to 3.5–5% combined with better management practices had increased the capacity factors of these reactors to 91.8%, so that an increased amount of electrical energy was now being produced by the present 104 U.S. nuclear reactors without increasing their number.

The new reactors to be built, Peddicord said, will be of generation III and III+, which use simpler standard designs with passive features (50% fewer valves, 35% fewer safety grade pumps, 80% less pipe, 45% less seismic building volume, and 85% less cable), thus resulting in greater safety and reduced cost. With these designs coming from such collaborations as Toshiba and Westinghouse, and General Electric and Hitachi, Peddicord also observed that the nuclear power industry had become international.

Peddicord went on to say that generation IV reactors would utilize a sustained nuclear cycle with greater safety. One of them is the molten salt breeder reactor described in Resource #2 in our Fall 2010 issue. These would be needed by 2050, with world population expected to increase from its present six billion to ten billion and per capita energy use two-and-a-half times what it is now, as more of the world's population rises to the level of Western standards. When asked about the failure of France, the generator of the largest percentage of its electrical energy from nuclear fission, to develop a successful breeder reactor, Peddicord acknowledged the technical challenges of breeder reactors and cited them as the reason for France's failure. But he also saw the leadership in breeder reactor technology shifting to Russia, India, and China. He foresaw a future in which breeder reactors would be used to generate hydrogen fuel to replace our present use of oil, leaving a graph of petroleum use *vs.* time to be just a blip.

Although radiation from nuclear radioactivity has long been used in medical treatment, particularly in treatment of cancer, the proton therapy described by Nancy Mendenhall of the University of Florida's Proton Therapy Institute in her plenary on "State-of-the Art Nuclear Medicine" presented the reasons that this latest therapy is much more effective. Cancer affects one in every three or four Americans and is the second leading cause of death, arising from a single mutated cell that can grow locally or metastasize, she began. When cancer is treated with radiation, the radiation damages whatever cells it hits, and the amount of response to radiation is determined by the dose and the volume to which it is applied.

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The Warming of Antarctica

The message of Professor Oscar Schofield from the Coastal Ocean Observation Laboratory, Institute of Marine and Coastal Sciences, Rutgers University, to the students attending his Science on Saturday lecture at the Princeton Plasma Physics Laboratory on 5 March 2011, was threefold:

1) Science is fun – an adventure of exploration.
2) The Earth is changing, and scientists are needed to meet its challenge.
3) The younger generation is needed to produce those scientists. Upon entering college, students should seek experience in a lab.

The Earth changes addressed by Schofield, in his talk titled "Exploring the Changing Biology on a Melting Antarctic Peninsula," were those he has experienced in his years of research at Palmer Station on the Antarctic Peninsula. That peninsula is the world's fastest warming place, he said. The perennial ice is gone – only sea ice, "grown" in area equal to that of the U.S. every Antarctic winter, remains, and climate warming is reducing that as well. The Larsen ice shelf has disappeared, and the Wilkes ice sheet is following. Glaciers have retreated to the point that skiing is no longer possible on them, and plants are growing on the ground that now appears where ice once lay (while at the same time, the total amount of marine plant material is decreasing).

Schofield said that the heat warming Antarctica is coming from the deep ocean. This heat causes freshwater ice sheets to melt into the ocean, and this changes the overall ecology, dominated by phytoplankton and krill. Decreasing ice cover is causing subpolar species to increase at the expense of ice-loving polar species. One such polar species which Schofield follows is the adelie penguin. They like silverfish and krill, but forced regurgitation shows that they are now dependent solely on krill. As krill becomes replaced by "jellies," the end of the adelie penguin's food supply will spell their end. Schofield said that a moister atmosphere and its attendant snow (which drowns penguin eggs) are also endangering the adelie penguins.

A seagoing research ship costs $70,000 per day, Schofield stated. But now research can be done more cheaply and year-round by 29 robots, controlled from New Jersey. Robots enable anyone to measure anything, anywhere, and this is why Schofield believes the younger generation will rise to the challenges expected of it. Robots have changed what it means to be an oceanographer. Future sea expeditions will do only things that robots can't do.

Nuclear Physics

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Mendenhall showed graphs of radiation dose *vs*. depth of deposition for gamma rays, X-rays, and protons. The proton graph, she noted, showed a sharp peak (the "Bragg" peak), which allows a maximum dose to be applied to the target, with low entrance dose and no exit dose. This, she observed, makes a proton a more efficacious source of radiation for cancer treatment. The 230 MeV protons from the Proton Therapy Institute cyclotron have a 32 cm penetration depth, Mendenhall said, and they must be attenuated if the target is at a smaller penetration depth. If a range of depth of deposition is required, a range of energies is needed, and this is achieved by a rotating range modulation wheel. The proton beam also passes through an aperture matched to the shape of the targeted tumor. All these measures act to insure that *only* the targeted tumor receives radiation.

The major downside of proton therapy is its expense, as was already reported in our coverage of the Spring 2009 meeting of the New Jersey Section of AAPT in our Winter/Spring 2009 issue. At that time there were only four proton therapy centers in the U.S., but Mendenhall reported that this number has now doubled. But the cost remains high: $120 million for each facility.

Galilean *Dialogue*

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program (which he noted would require a smaller number of high-quality teacher preparation institutions). He also invited them to check out his website <www.scienceeducationencore.org>, where he has now posted his *Dialogue*, also to visit <www.archive.org/details/projectphysicscollection>, where he has archived all the print materials of the Project Physics Course.

bugs in computer chips

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process 2^t variables, and the worst case scenario would require 2^{2t} tests, and this would make it harder to get bug-free chips.

Daunting as the problems he proposed seemed to be, Malik encouraged students to be optimistic, observing that most things don't work out the first time. "If everything seems like a big rock, it will be," he said.

ACS publishes new middle school curriculum

In an effort to improve the teaching of chemistry at the middle school level, the American Chemical Society has published online its new *Chemistry for Life* middle school chemistry curriculum. It consists of five chapters with the following titles and subtopics:

1. “Matter – Solids, Liquids, and Gases”

    1. Molecules Matter
    2. Molecules in Motion
    3. The Ups and Downs of Thermometers
    4. Moving Molecules in a Solid
    5. Air, It’s Really There

2. “Changes of State”

    1. Heat, Temperature, and Conduction
    2. Changes of State – Evaporation
    3. Changes of State – Condensation
    4. Changing State – Freezing
    5. Changing State – Melting

3. “Density”

    1. What is density?
    2. Finding Volume – The Water Displacement Method
    3. Density of Water
    4. Density – Sink and Float for Solids
    5. Density – Sink and Float for Liquids
    6. Temperature and Density

4. “The Periodic Table & Bonding”

    1. Protons, Neutrons, and Electrons
    2. The Periodic Table
    3. The Periodic Table & Energy Level Models
    4. Energy Levels, Electrons, and Covalent Bonding
    5. Energy Levels, Electrons, and Ionic Bonding
    6. Representing Bonding with Lewis Dot Diagrams

5. “The Water Molecule and Dissolving”

    1. Water is a Polar Molecule
    2. Surface Tension
    3. Why Does Water Dissolve Salt?
    4. Why Does Water Dissolve Sugar?
    5. Using Dissolving to Identify an Unknown
    6. Does Temperature Affect Dissolving?
    7. Can Liquids Dissolve in Water?
    8. Can Gases Dissolve in Water?
    9. Temperature Changes in Dissolving

6. “Chemical Change”

    1. What is a Chemical Reaction?
    2. Controlling the Amount of Products in a Chemical Reaction
    3. Forming a Precipitate
    4. Temperature and Rate of a Chemical Reaction
    5. A Catalyst and the Rate of Reaction
    6. Using Chemical Change to Identify an Unknown
    7. Energy Changes in Chemical Reactions

Lesson plans using the 5E learning cycle and student activity sheets for each of the chapter subtopics can be downloaded individually, or the entire 615-page book of Middle School Chemistry lessons can be downloaded all at once. The URL to visit is <http://www.middleschoolchemistry.com>.

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

30 Jul - 3 Aug 11, Summer Meeting of the American Association of Physics Teachers, “Communicating Physics Outside the Classroom,” Creighton University, Omaha, NE. Visit <www.aapt.org>.

20-22 Oct 11, Second China International Nuclear Symposium, Hong Kong. Visit <http://www.wna-symposium.org/china/index.html>.

28 Oct 11, Center for Sustainable Energy’s Seventh Annual Alternative Vehicle Technology Conference and Expo, Lehman College, City University of New York. Call Yolanda Rodriguez or Reuben Rodriguez at (718)-289-5332.

28 Nov – 2 Dec 11, Materials Research Society Fall Meeting, Boston, MA. Visit <www.mrs.org/fall2011>.

6-8 Mar 12, Building Energy 12, organized by the Northeast Sustainable Energy Association, at the Seaport World Trade Center, Boston, MA. It brings together architects, engineers, builders, designers, policymakers, educators, developers and building managers for three days of networking, accredited educational sessions and a high-level trade show. Visit <http://www.nesea.org/be12/>. Proposals may be submitted until 6 June 2011 to Mary Biddle, conference director, at <mbiddle@nesea.org>.

The Neuroscience of Magic

The title of the talk given by Stephen Macknik and Susan Martinez-Conde at the Princeton Plasma Physics Laboratory on 22 January 2011 was nearly the same as that of the book they have just published: *Sleights of Mind: What the Neuroscience of Magic Reveals About Our Everyday Deceptions* (Holt, New York, 2010). What we see is mapped onto our visual cortex, they said. An illusion is a subjective perception that doesn't match the real world. Scientists study illusions to understand the brain. Magicians use illusions to entertain – and sometimes they use multiple illusions: special effects, secret devices, optical illusions, visual illusions, and cognitive illusions (including misdirection of attention, these occur at higher brain levels).

The audience was given an experience of the first type of illusion recorded in human history – Aristotle's observation that adjacent rocks appeared to move after he shifted his gaze away from looking intently at a waterfall. We were also exposed to "change blindness" – an interruption that substitutes one thing for another without the change being noticed – by failing to observe 21 changes in a filmed "whodunit?" sequence. It's easy not to notice what you're not looking for, Macknik said. Paying attention to one task keeps one from seeing other things. Magicians take advantage of this, he went on, by getting the brain – through inhibitory neurons – to suppress neurons which would otherwise make us aware of distractions (this is especially true for flying doves). In this way, magicians have anticipated neuroscience.

Magic can also result from misdirection in time as well as in space, Macknik continued, and magicians make use of several types of misdirections at once. But once a person understands a misdirection, she or he cannot be fooled by it again.

Among the things learned about neuroscience by magicians and the advice offered by Macknik and Martinez-Conde were the following:

1. Multitasking is a myth, so do only one thing at a time.

2. Memory is fallible, so record important things as they happen. (Magicians often recap a trick fallaciously in order to keep observers from being able to figure it out.)

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Two Curricula Address Alternative Fuels

Two curricula recently described in *The Science Teacher* have been developed to address the issue of alternatives to gasoline to fuel transportation. On page 52 of the September 2010 issue (volume 77, number 6) Mark Schumack, Stokes Baker, Mark Benvenuto, James Graves, Arthur Haman, and Daniel Maggio describe their curriculum, "Fueling the Car of Tomorrow." On page 35 of the December 2010 issue (volume 77, number 9) Sara Krauskopf describes her lesson on "A Life-Cycle Assessment of Biofuels."

"Fueling the Car of Tomorrow" consists of seventeen activities, which "can be offered individually as supplements to biology, chemistry, or engineering classes and completed in one or two class periods, or the entire series can form the basis of a semester-long or even year-long preengineering course." Each activity begins with a one- to three-page introductory narrative, which is followed by questions for class discussion and an activity for students to do. The activities close with postactivity analyses and a postactivity assessment. Teacher and student versions can be downloaded in pdf from the website of the College of Engineering and Science at the University of Detroit Mercy, where the curriculum was developed: <http://eng-sci.udmercy.edu/pre-college/alt_fuel_curriculum>. Required Supplemental Materials can be downloaded as a .zip file from the same website.

The lesson on "A Life-Cycle Assessment of Biofuels" was designed to "be used in an integrated science, biology, or environmental science course, to take two 50-minute class periods." After students respond to a formative assessment on whether they think gasoline or ethanol is a better fuel, they are grouped at stations corresponding to the stages by which ethanol fuel is made and used: plants, farming practices, feedstock transport, refining (split into two substations, fermentation and plant operation), product transport, and the car. The group at each respective station is to determine the energy and matter input and output at each. These inputs and outputs are then synthesized into the overall energy and matter input for the entire system of producing ethanol fuel. To download the materials for this lesson, visit the website for the Great Lakes Bioenergy Research Center, <www.glbrc.org/edcation/educationalmaterials>, scroll

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Earth: Still a Special Planet?

by John L. Roeder

One of my most vivid memories of attending the Centennial Meeting of the American Physical Society in 1999 was a talk by Geoff Marcy on the then infant field of locating exoplanets (planets orbiting stars other than our Sun). Because the exoplanets first identified were large and unusually near the stars they orbited, in highly elliptical orbits, Marcy then portrayed Earth as being exceptional in comparison to the planets known at the time.

Twelve years later, on 9 April 2011, Marcy was invited to present the Henry R. and Gladys V. Irons Public Lecture in Physics and Astronomy at Rutgers University. In his talk on "The Search for Earth-Like Planets and Life in the Universe," Marcy focused on what has been learned from observations made by the 1 meter-diameter Kepler telescope, which photographs a field of 150,000 stars in a square field 10 degrees on a side every minute and can detect variation in brightness of 0.01%. The first exoplanets were detected by measuring their ability to cause the position of their star to wobble, and this was easiest to observe when the exoplanet was large and nearby. But, by relying on measuring the dimness in the light signal emitted by a star when a planet makes a transit in front of the star, the Kepler telescope can detect exoplanets of all sizes and orbital radii. Of the 1235 candidates so identified by this approach, Marcy said that exoplanets with radii between one and two Earth radii dominate.

One of the stars that Kepler photographs in the constellation Cygnus has been given the name Kepler-10. Two exoplanets have been observed orbiting it, one with a period of revolution around its star of only 0.83 days, a radius 1.4 times that of Earth, and a density of 8.8 grams/cm^3. (In addition to measuring an exoplanet's mass by the effect it has on causing its star's position to wobble, exoplanetary masses can be determined by observing the gravitational interaction among multiple exoplanets orbiting the same star.)

Regarding the reason that living organisms have not been discovered elsewhere in the universe, Marcy raised several questions:

1) We believe that the laws of physics and chemistry are the same throughout the universe, but is this also true for the laws of biology? Is there another compound that can play the same role as DNA?

2) In the 200 million years of dinosaurs on Earth, their cranial size never changed. After a billion years of existence, jellyfish continue to be happy without brains. Must life elsewhere necessarily evolve into an intelligent form?

3) The Earth is 0.03% water. If it were less than 0.01% water, it would be a desert. If it were more than 0.05% water, it would be a "water world." Is Earth more special than we thought?

Marcy also observed that life formed on Earth quickly (only half a billion years) after the Earth formed, and it has demonstrated its ability to thrive in the most unpleasant environments (he cited the bacteria that provide the color in the highly acidic environment of Yellowstone National Park). The one ingredient that seems to be required for the formation of life, he said, is liquid water. Though life may still be found in the ocean beneath the surface ice of Europa, Marcy ventured that we must look outside our solar system for other intelligent life. Citing the difficulty of travel for humans among the stars, he expected that Earth would send out a robotic probe to Alpha Centauri in the next hundred years. He also urged the continued search for extraterrestrial intelligent life and cited the Allen Radio Telescope Array to be built at Mount Lassen as a way to do this.

Magic

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3. If you make a mistake, keep moving forward: Magicians use humor and empathy to lower the guard of their audience.

4. Attention enhances one part of the world while suppressing everything else. Complex decisions require making a full list of relevant facts.

(*Editor's Note*: Macknik and Martinez-Conde's *Sleights of Mind* is reviewed in this issue.)

Alternative Fuels

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down to "SUSTAINABLE ACTIVITIES" and download the Biofuels 101 package.

Worms, Bacteria, and Cancer

There are many facets to the role of evolution in medicine, ranging from evolved genetic difference in an organism's response to drugs and ability to resist disease, sometimes with a negative by-product (as in the case of sickle-cell anemia and protection against malaria) to the evolution of virulence and response to drugs by disease-causing agents and the evolution of causes of disease. Because these facets are so varied, Biology Professor Stephen Stearns of Yale University observed that they are found in different courses in medical school.

Stearns spoke at the 8 January 2011 "Science on Saturday" lecture at the Princeton Plasma Physics Laboratory. In his talk on "Major Themes in Evolutionary Medicine," he addressed two of them: what he called the "Hygiene/ Old Friends" hypothesis and the role of evolution in the development of cancer.

The "Old Friends" related to hygiene are worms and bacteria, and the hypothesis is that the human immune system evolved with the presence of worms and bacteria in our bodies. Removing these organisms rids us of the infections that they cause, but it also results in inappropriate response of our immune system and an increase in the incidence of such autoimmune diseases as allergies and diabetes. This happens, Stearns said, because worms produce substances that block immune responses in their host that would kill or expel them. These substances disable pathways that would elicit allergies and asthma. The strategy here is to develop medicines containing the substances produced by the worms – in order to reap their benefit without the ill effects of infection the worms would produce. In other cases, the development of the human immune system results from the genomes of our bacteria rather than from our own genome.

In discussing cancer, Stearns emphasized how cancers arise from proto-cancers which continually evolve in our bodies, with most of them killed by our immune system. They result from a sequence of seven to nine mutations that destroy tumor suppression mechanisms, and some of these mutations can be inherited. These mutations usually arise in stem cells and are *invasions* of body tissue that take over the resources of the body to further their own development.

Stearns articulated the following sequence of events for the development of pancreatic cancer: 1) more than

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Micromidas: Waste Solids to PHA

A chemical engineer by training, Ryan Smith is a man with an idea to solve two problems: what to do with the solids in wastewater, and what to do about the permanence of plastics in our waste stream. At a gathering on 17 March 2011 hosted by Margaret Honey and Melissa Vail, President and Trustee, respectively, of the New York Hall of Science, Smith spoke about what he has done to implement his idea – an idea, he said, was inspired by his dog, Jackson. When Jackson cleared a picnic table of plastic waste, Smith told us, he realized the liability posed by that plastic's permanence.

He went on to describe how he had founded Micromidas to convert wastewater solids into biodegradable plastics by a multiple bacterial fermentation process. The product is a fully polymerized plastic, polyhydroxylalkanoate (PHA), made from three-carbon esters, and since three-carbon esters are recognized by organisms responsible for biological decay, they will decompose.

Smith reported that he uses wastewater to feed his bacteria, because the cost of sugar to feed them is greater than the cost of oil in the conventional process of making plastic. The wastewater solids are a free feedstock for him, and extracting them from the waste water is a cost saving for municipalities (and, because of this, his PHA manufacturing plants would ideally be collocated with municipal wastewater treatment plants). Rather than look for carbon in underground oil, Smith said, he uses carbon in wastewater, and the waste avoidance thus achieved has emerged as Micromidas's primary product.

Smith added that he screens his bacteria for their productivity. He evaluates this by a cycle of feeding a batch of bacteria, then starving them and measuring how much PHA they have produced. The most prolific bacteria are retained for further duty. Now having finished its pilot research, Micromidas is now preparing to scale up to transform the solids in liquid waste in Sacramento (CA) into PHA; after that, Smith is aiming to do the same in a larger city like Los Angeles.

While he is a chemical engineer himself, he emphasized that he will be looking to hire scientists with varied backgrounds and most important, the ability to learn on the job, in this new field dependent on nimble thinking and innovation.

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AC *v.* DC

Joseph J. Cunningham is Adjunct Professor of Railway Systems at TCI College of Technology. He is also a walking encyclopedia about transportation and electric power systems. No surprise, then, that his talk on "The Myth of the 'War of the Currents' (AC *v.* DC)" at the17 December 2010 meeting of the Physics Club of New York at New York University was most informative (even if it didn't cover all the more than 30 "significant dates" Cunningham listed on his handout).

Cunningham began by stating that "war" is too strong a term to refer to the competition between AC and DC. Any adopted technology, he went on, must be possible, practical, and economically feasible. It is also subject to displacement by further technological sophistication.

Cunningham noted that the original electric power experimenters used DC, because it came from batteries. AC came along as a result of generators, though commutators could convert it to DC.

Thomas Edison's original DC electrification was a technological success, Cunningham stated, but it was initially an economic failure – the development of the motor by Frank Sprague helped to change this by making an addition to the daytime load. Initially separate generating stations were employed for each three square mile district, because the transmission range was about only a mile.

Lengthening transmission range required higher voltages. According to Cunningham, William Stanley is normally credited with developing the voltage transformer in the U.S., but this required AC. Sprague advocated central generation of AC to substations, with DC transmission from substation to consumer, because "power factor" problems led to less efficient local distribution of AC power than its DC equivalent.

In order to bring Charles Steinmetz into his employ, Cunningham said that Edison's General Electric Company bought Steinmetz's employer, Eickemeyer. Although DC still prevailed over AC, AC had gained acceptance for long-distance transmission, based on the system Steinmetz designed, with mathematical formulae providing a solid engineering base. Cunningham also noted that batteries could be used to meet peak demand in DC systems.

In contrast with Edison's DC system, George Westinghouse led the promotion of AC, using the polyphase system patents of Nikola Tesla. Cunningham stated that Tesla's attraction to AC came in trying to achieve a more efficient use of a motor and added that AC also had the advantage of using less copper. There were at the time three types of electrical generation systems: 2000 volts for carbon-arc exterior lights, which predated Edison's electrification of homes in Lower Manhattan; 120 volts for households; and 400 volts for industry. Before the advent of substations, which were developed after Thomas Murray produced the first large-scale generating station, the energy was provided in New York City by 12 utility power plants and 775 private power plants, some used for electric power generation in department stores. Cunningham noted that the generator in the old B. Altman store at 34th and Fifth in Manhattan has subsequently been used in emergencies by the CUNY Graduate Center and the Science, Industry, and Business Library of the New York Public Library, presently at the same location.

Later, concern about the huge investment in substations led to the movement to use AC for residential transmission. The transformation from DC to AC in New York City, Cunningham said, occurred mostly between 1928 and 1937, with the last DC substation put out of commission in 1977 and the last DC customer retired in 2007.

To conclude, Cunningham made a point that AC and DC were not adversarial technologies but that each made its own valuable contribution to the electric power system: although he had been an AC advocate in his younger years, Tesla in his old age advocated DC for specialized long-distance transmission.

Worms, Bacteria, and Cancer

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ten years to develop a non-metastatic primary tumor, 2) five to six years to develop metastatic subclones, and 3) about three years to form metastases. Because of the time cancers require to develop, longer human lifespan has led to an increased incidence of cancer, Stearns observed, but he also cited the effects of such substances as tobacco, for which our evolution was not designed. Oral contraceptives have an effect as well, he said: they protect against ovarian cancer but increase the incidence of breast cancer. While the death rate from heart disease has been drastically reduced, only recently has it started to decline for cancer. Stearns attributed this to reduction in smoking, more effective treatment, and earlier detection.

Kastner hypothesizes common basis for language and tool use in humans

Darwin's *The Descent of Man* (1871) argued that humans had evolved by branching off from apes. Humans are known to have existed 180,000 years and to share a common ancestor with chimpanzees and bonobos seven million years ago. Humans are distinguished by fire, wheels, diagnosis of problems, and ideals – also complex tool use, grammatically structured language, mental state attribution, causal-logical reasoning, and culture (passing on of achievements to succeeding generations).

These were the prefatory remarks by Sabine Kastner of Princeton University's Neuroscience Institute and Department of Psychology in her Science on Saturday lecture at the Princeton Plasma Physics Lab on 19 February 2011. The title of her talk was "Words, Tools, and the Brain: Why Humans Aren't Just Another Ape," and it focused on tool use and how it illustrates building on brain systems of less-developed species.

Tool use is not limited to humans, Kastner pointed out: it is even found in crows. *Intelligent* tool use requires understanding cause-effect relationship, insight into the tool's relationship to the environment, ability to make the tool, and flexibility in using it. Even chimps are found to exhibit intelligent tool use, Kastner went on. But macaques, the "standard" Old World monkey for many years, don't use tools, although they can be trained to use them. Flexible tool use, she said, appears to be human specific, with tool building and use seen in the behavior of young children.

The oldest stone tools, Kastner observed, are 2.5 million years old. But chimps, who have mastered several symbols cannot be taught how to flake rocks into the shape of these old stone tools. Thus, she concluded, these tools reflect a first rich hominid culture and skill development.

The human brain has been remapped in two dimensions to show the regions involved in analysis, planning, and execution, Kastner continued. The human brain has been found to have a section for tool use not found in macaque brains. The dorsal object vision pathway and tool use region are found only in humans, she said.

Kastner went on to observe that patients deprived of their action recognition center do not know how to use tools or learn about new tools. On this basis, she hypothesized that the action recognition system is the basis for both tool use and language (which was initially based on gestures) – and hence also for social skills (not functional in people with autism). If this is so, she continued, the human action recognition system must be organized differently from that of monkeys (a hypothesis which she noted can be tested). Kastner concluded by venturing that it is the branching from the action recognition systems to those for tools and language that underlies the explosion in human development of technology over the past 30,000 years – after a long period of building the same types of stone tools.

Inertial Confinement: the "other" fusion energy

"Fusion is the energy of the future and always will be." This is how John Sethian of the Naval Research Laboratory began his Science on Saturday lecture, "KrF Lasers and Inertial Confinement, Another Path to Clean Fusion Energy," at the Princeton Plasma Physics Laboratory on 12 February 2011. Sethian then went on to explain how inertial confinement fusion is funded for its simulation of nuclear weapons (by the National Nuclear Security Administration) and that the US Department of Energy has challenge enough to fund magnetically-confined fusion, such as that at the Plasma Physics Lab.

As an energy source, fusion has several advantages, Sethian said: its materials are abundant, it produces no greenhouse gases, and it's safe. But all this is outweighed by the one disadvantage that it hasn't been made to work yet.

Inertially-confined fusion attempts to fuse nuclei of deuterium (hydrogen-2) and tritium (hydrogen-3) in a spherical pellet by heating it with a spherically-symmetric array of lasers – many times a second. Naval Research Lab's choice to achieve inertially-confined fusion is a krypton fluoride laser pumped by electron beams. It requires half a million volts and 200,000 amperes of electric current, for a total power consumption of a tenth of a terawatt – but for only very short pulses. In Stage I of their work their goal is to get all the bugs out of the krypton fluoride laser so that 30 of them can be assembled for a test for fusion in Stage II. Stage III is generation of electric power. Sethian opined that Stage II could be achieved by 2030.

Right now a coal car full of coal can generate a gigawatt of electric power (the amount from a conventional power plant) for ten minutes. A coal car full of deuterium-tritium pellets, he said, could produce the same power for seven years.

Coal-generated electricity: less CO_2 than an ICE and more efficient than hydrogen

The Infusion Tips column in our Fall 2008 issue presented the calculations of Richard Flarend of Pennsylvania State University that, with sufficiently high cost, furnace oil is a more costly way to heat a home than electrical resistance heating. Now he presents calculations to show that an automobile powered by coal-generated electricity emits less carbon dioxide than a car with a gasoline-burning internal combustion engine (ICE).

He cites figures from the Environmental Protection Agency that a gallon of gasoline emits 8.88 kg of carbon dioxide and from the Energy Information Administration that generation of a kilowatt-hour of electrical energy from coal emitted 0.95 kg carbon dioxide in 1999. He compares the Nissan Leaf, which travels 100 miles on 24 kWh electrical energy, and a comparable small car traveling 33 miles on a gallon of gasoline, thus needing about three gallons for the 100-mile trip, to establish a correspondence between 1 gallon of gasoline and 8 kWh of electrical energy. But the gallon of gasoline's emission of 8.88 kg carbon dioxide exceeds the 7.60 kg carbon dioxide from the 8 kWh of electrical energy.

Flarend adds that since coal-generating power plant efficiency has increased at a rate of 1% annually, the advantage of the electric car has only increased since 1999. Moreover, he points out that carbon dioxide generated at single point source power plants is a lot easier to collect than the carbon dioxide generated by the diffuse source of individual automobiles. The same argument, he continues, applies in comparing the advantages of electric heat over individual oil-burning furnaces.

Using Electricity to Make Hydrogen or to Run a Motor

According to the presentation by chemist Robert Drake to the Physics and Chemistry Teachers Clubs of New York City at New York University on 8 April 2011, electric vehicles are more than three times as efficient as hydrogen-fueled vehicles, regardless of the source of electricity. Drawing from the Wikipedia article on the hydrogen economy, Drake showed that electrical energy from any source energizes an electric lithium vehicle's lithium-ion battery with 93% efficiency, and that this energy is converted to the motion of the car with 93% efficiency, for an overall efficiency of energy conversion from elec-

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SCONYC Keynote: Forensics for All!

"Forensics for All!" was the subject of Bud Bertino's keynote address at the 34th annual Conference of the Science Council Of New York City (SCONYC) at Stuyvesant High School on 2 April 2011. Bertino, retired from Canandaigua Academy and author of *Forensic Science: Fundamentals & Investigations*, began by observing that forensics draws from many disciplines and thus fosters interdisciplinary learning. He added that forensics also lends itself well to group work and engages students, because everyone loves to solve a mystery. He said that he himself used it to keep his AP biology students interested after their AP exam.

He urged teachers interested in teaching forensics to start with a scenario to engage students. Keep it simple and avoid gore, he recommended, and depict it with a "crime scene" set up in the classroom – one that can be left in place as long as it is needed. In setting up the crime scene, think about the evidence to include; and, in the scenario, think about the number of suspects.

Bertino pointed out that crimes are solved on the basis of Locard's Exchange Principle: a crime perpetrator will take something from the scene *but will also leave something behind*. Among the sources of evidence to consider, Bertino listed the following:

- Hair (the medullary index – ratio of inner to outer stem diameter when viewed under a microscope – is less than a third for human hair, greater than a third for non-human hair)
- Fiber (pollen embedded in fiber indicates where the fiber has been)
- Blood
- Tool marks
- Chromatography (to analyze ink in ransom demands)
- Impressions (*e.g.*, footprints – these give students good experience in measurement)
- DNA
- Fingerprints
- Ballistics
- Glass analysis (including measurement of refractive index)
- Sand (Bertino showed pictures of sand from different locations as evidence to show that sands are distinguished by their location of origin)
- Skid marks (to determine the speed of a car from their length – for more details, see related article in our Winter/Spring 2009 issue)

Lipson seeks to automate discovery

"The Robotic Scientist: Can Scientific Discovery be Automated?" was the title of Cornell University Professor Hod Lipson's talk at the Princeton Plasma Physics Laboratory on 29 January 2011. Noting that biology is a treasure chest for engineers (it has invented a lot of things for engineers to use and engineers can help to understand it), Lipson reported how he sought to have programs evolve robotic parts into a robot, and simple machines that can crawl were produced. He also reported making a robot and seeking to breed programs to control it.

But he found that the steps from simulators to evolved robots and from evolved robots to built robots to be too expensive or time-consuming, so he instituted a loop, whereby data from the built robots is used to make better simulators. Of the many models that resulted, Lipson chose the one with greatest discrimination, just as one heralds an experiment that best discriminates among competing theories. He found that a four-legged robot adapted by finding a new way to "walk" when the tip of one its legs was removed.

Lipson then turned to investigate data gathered from the behavior of systems. He sought to breed equations from mathematical terms to match these data, with regression used to calibrate the coefficients. He was not successful in developing a mathematical model of the behavior of the stock market in this way and was able to produce only already-known approximations to prime numbers. He was able to obtain a formula for nuclear binding energy, but he showed that the already-derived Weizsäcker formula fits the binding energy data with a higher correlation coefficient.

From time series data derivatives can be constructed to develop differential equations, Lipson went on. From the time series data describing the behavior of a cell, he was able to generate seven such equations. When he incorporated time delays, he was able to produce simpler equations than those biologists had inferred and published. Moreover, his equations had the advantage of being symmetric, but there was no way to understand their meaning. To facilitate understanding, it was decided to search the data for invariants.

To help others looking for ways to extract meaning from their data, Lipson has published his code as *Eurequa* so that it can be accessed by Googling that name. He

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New Tech Devices

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than carbon-14's range of reliability. ESR (electron spin resonance) provides another way to determine the age of quartz, fossilized teeth, flint, and calcium carbonate in limestone, coral, and egg shells. Biology and paleontology not only inform each other, but geology, genetics, climate studies, oceanography, cytology, and dendrochronology researchers pool their resources in support of shared knowledge. This integration of science and technology aids medicine, anthropology, history, and even linguistics research. Archeologists, for example, used to operate in isolation from the earth sciences. Now, they, along with other social sciences, rely increasingly on the natural sciences, and sometimes return the favor to the "pure" sciences in joint solving of more mysteries.

Science magazine recently reported that in the early nineteenth century new technology was accepted by the general population in about 66 years. From 1880 to 1920 the acceptance period shrank to 27 years. Despite the flood of new technology, the transition time since 2000 may well have shortened to 10 years. Complexity will certainly increase with the flood of new devices and the rise of Internet-accessible knowledge. Instead of causing us worry, perhaps that change calls for a celebration.

(*Editor's Note*: John White wishes to call his readers' attention to the fact that, no sooner than he wrote this story, another example of his thesis occurred, and both *The New York Times* and National Public Radio picked up on it on 13 April 2011. This example was Cisco's announcement that it was terminating manufacture of the Flip video camera. While the *Times* coverage cites analysts questioning Cisco's acquisition of Flip in the first place, it also notes that "with its versatility in recording video and still images, as well as its ability to perform myriad other functions, the smartphone has since proved to be a far more desirable product than a single-function device like the Flip." Ironically, I had been introduced to the Flip camera only the day before by a pair of students working on a project.

I have seen the demise of another single-function device, the immersion coil for heating water – a device I use to teach Active Physics but can now purchase only online. Anticipating the thesis of White's article, I had speculated that people stopped buying immersion coils because they could heat water just as fast with a microwave oven – but my Active physics students calculate that the immersion coil can also do so twice as efficiently.)

From Earth to *Eaarth*

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sease-bearing insects. But the world as we know it has changed, he reiterates – "even if we don't quite know it yet." McKibben calls it "Eaarth." He sees it characterized by "more thunder, more lightning, less ice" (p. 5) and manifested by an expansion of the tropics by "more than two degrees of latitude north and south since 1980." (p. 5) And "As the tropics expand, they push the dry subtropics ahead of them, north and south, with 'grave implications for many millions of people' in these newly arid regions," (p. 5) with Australia and the American Southwest particularly affected. More thunder and lightning have been seen in longer hurricane seasons with more hurricanes reaching previously untouched locations. Less ice means deprivation of traditional sources of water from spring runoff, leading to drier hot seasons and longer fire seasons, while warmer winters kill fewer pests and thus allow greater infestation of trees, endangering forests to make a carbon source out of what was once a carbon sink. And increased carbon dioxide in the oceans has lowered their pH from 8.2 to 8.1, with 7.8 expected by 2100, thus endangering marine shellfish.

Twenty years ago we fixated on the effects of doubling the then atmospheric carbon dioxide concentration of 275 parts per million (ppm), McKibben writes, but by 2004 we learned that 450 ppm was the limiting concentration to "avoid most long-term effects." (p. 14) Then in 2007 James Hansen pronounced 350 ppm as the threshold for dire effects, and now we're already at 390 ppm. Kevin Anderson in 2008 predicted an ultimate concentration of 650 ppm, even with draconian reduction of emissions within a decade, and a team from M.I.T. predicted between 600 ppm and 725 ppm, even if all the pledges made at the Copenhagen Conference in December 2009 were kept. Global warming is happening *now*, McKibben emphasizes, and it's happening before we expected it. Moreover, it's showing signs of positive feedback, from reduced albedo to methane emission from melting clathrates, and carbon dioxide sinks are getting more congested, now removing only 559 kg of every ton emitted, as opposed to 600 kg 50 years ago.

McKibben points out that switching to biofuels in 2008 put 40 million people "at risk of hunger," and 2009 added a billion more. "We're hard at work transforming [the Earth] -- . . . sabotaging its biology, draining its diversity, affecting every other kind of life that we were born onto this planet with. We're running Genesis backward. . . ." (p. 25) He writes that in order for animals to accommodate higher temperatures with a higher surface-to-volume ratio, their size will decrease. "We *may*, with commitment and luck, yet be able to maintain a planet that will sustain *some kind* of civilization, but it won't be the same planet, and hence it can't be the same civilization. The earth that we know – the only earth we ever knew – is gone." (p. 27)

We are "bipedal devices for combusting fossil fuel," McKibben continues (p. 28), each of us using 25 barrels of oil annually, with each barrel providing the equivalent of a decade of human labor. This has given us prosperity, global warming, and acid oceans. Now that we've destabilized our climate, we're close to peaking our use of the fossil fuels we've done it with. Paying for fossil fuels constitutes a tenth of gross domestic product, and most of the rest comes from burning it or using it as petrochemicals. Sadly, the fossil fuel in greatest supply, coal, is the one producing the most climate destabilization. McKibben observes that oil price spikes have preceded seven of the eight most recent recessions and suggests that rising oil prices have contributed to declining property values in exurbia.

Because Thomas Friedman in *Hot, Flat, and Crowded* regards the modern world as a "growth machine," he advocates "inventing a source of abundant, clean, reliable, cheap electrons, which would enable the planet to grow in a way that doesn't destroy its remaining natural habitats" rather than no growth at all. While McKibben agrees with this strategy, thus differing from Lovelock, and expects it to be implemented faster than is presently expected, he also feels that it cannot be implemented fast enough "to preserve the planet we used to live on." (p. 53) This is because three quarters of the power plants expected to be operating in 2020 are already built, so changing to more than 25% of electricity from renewable sources requires decommissioning plants before the end of their useful life. Moreover, 85% of the 2340 lobbyists registered to work on climate change will act to continue a climate favorable to fossil fuels. Although nuclear energy emits no greenhouse gases and therefore is more appealing where climate change is concerned, McKibben finds it unattractive from an economic point of view and thus unlikely to play a major role [another point of disagreement with Lovelock]. Eliminating only one ninth of global warming in the next 40 years requires adding four times the number of windmills in place in 2007 every year, and this will still leave us with 450 ppm carbon dioxide.

McKibben also notes that we have allowed the infrastructure of planet Earth to deteriorate, and upgrading it to the standards required by the new planet Eaarth will be even more expensive. Although reduced Himalayan

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snowcap and rising sea level wrought by global warming threaten salt water incursion in Bangladesh, the already-present danger is increased incidence of dengue fever, which results from the *Aedes aegypti* mosquito, which bites from dawn to dusk. And when there are short-term medical bills to pay, there is little money for long-term investments designed for future improvement or problem avoidance.

Among the cheapest ways for solving today's problems today is burning more coal, especially in China, but McKibben sees China as now experiencing the consequences of being the world's largest generator of carbon dioxide. Like the rest of the developing world playing "Ginger Rogers to America's Fred Astaire" (p. 79), China is seen as willing to change from its efforts toward economic growth through fossil fuels but only with financial and technical assistance from the developed countries responsible for most global warming in the first place. McKibben credits President Obama for recognizing that this must come from incremental political change. But he also recognizes that it will be more difficult in a world where less runoff and rising seas will reduce agricultural output and increase the likelihood of war. There are ways to avoid warfare on the future Eaarth, McKibben adds, but we must realize that "Eaarth is an uphill planet" (p. 86), not the flat Earth of Thomas Friedman. One characteristic, resulting from higher oil prices, is more expensive transportation and its deflation of global trade, which will make American labor more competitive.

McKibben credits *The Limits to Growth*, coupled with E. F. Schumacher's *Small is Beautiful* and the Arab Oil Embargo, all of the 1970s, with providing a window of opportunity to achieve the "ecological and economic stability . . . so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his or her individual human potential" envisioned by *Limits*. Then he laments that we blew it with the election of Ronald Reagan, in whose shadow "we pumped the carbon dioxide into the atmosphere and the oil out of the ground" (pp. 94-95) for the next 25 years. Because we reduced water and air pollution, we patted ourselves on the back. But he credits The Club of Rome (which commissioned *The Limits to Growth*), Schumacher, and Jimmy Carter for getting it right: "You grow too large, and then you run out of oil, and the Arctic melts." (p. 97) In this way we have thus "foreclosed lots of options" (p. 99) for our future.

McKibben observes that Jared Diamond's *Collapse* (reviewed in our Winter/Spring 2006 issue) describes the demise of many past cultures, often soon after they reached their peak (when their impact on the environment also peaked). Should this now happen to us as a global culture, we would have nowhere else to go. But rather than prepare for a final battle or surrender, McKibben urges that "*we might choose instead to try to manage our descent* . . . aim for a *relatively graceful decline*." (p. 99) To do this, he writes, we just do two things: 1) "Mature" (p. 99) – realize that further growth on a finite planet is not feasible and recognize that our best days are not ahead of us "in the way we're used to reckoning 'best.'" (p. 100) 2) "Figure out what we must jettison" (p. 101) – "cheap fossil fuel and the stable climate that underwrote huge surpluses of food" enabled complex relationships that have made us vulnerable. "We're moving quickly from a world in which we push nature around to a world where nature pushes back. . . . But we've still got to live on that world, so we better start figuring out how." (p. 101) [Lovelock would see this as an action of Gaia.]

According to McKibben, "sturdy" and "steady" must be the bywords of planet Eaarth, and "anything too big to fail is by *definition* too big." (p. 105) American freedom began from protests of small local groups against the rule of a larger, distant power, he recounts. Only later did those groups find the need to coalesce into a nation and take on National projects, from the Louisiana Purchase to the Moon landing and dismemberment of the Soviet Union. But McKibben sees that while China, only recently showing the spurt of growth that characterized the last 200 years of American history, still has National projects like its dams, there are no more such projects for the U.S. We now have a national government bigger than we really need and should focus on maintaining what we have (*e.g.*, our infrastructure) rather than getting more, as individuals change their lifestyle in their older years.

McKibben continues that "we are heir both to the wealth [our ancestors amassed] and to the increasingly degraded planet it came from. We have to make that wealth last us. We had better not squander what inheritance we still have, and we had better figure out how to share some of it with the people already suffering from the environmental woes our profligacy caused. That means reshaping our society." (p. 217) That reshaping should be based on local community, which is also the focus of projects which should replace former National ones. McKibben gives examples from his living in Vermont and notes that local dependence on energy would reduce the need for military protection of our access to foreign oil.

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Collaboration

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one is consciously aware of exactly what the group is doing or how it works." (p. 28)

". . . organizations emphasize order and control, and yet improvisation seems to be uncontrollable . . . . leaders of innovative groups are active participants . . . more like a peer than a boss." (p. 34)

Sawyer's graduate school professor Mikaly Csikszentinihalyi, "coined the term 'flow' to describe a particular state of heightened consciousness." Sawyer expands on this to list ten conditions which characterize what he calls "group flow," in which a group is focused on communicating with each other and working toward an accepted well-defined goal and willing to accept failure as "a rehearsal for the next time."

Sawyer then goes on to emphasize the role of diversity within the context of group flow:

> Diversity makes teams more creative because the friction that results from multiple opinions drives the team to more original and more complex work. . . . Conflict keeps the group from falling into the groupthink trap. But conflict is difficult to manage productively because it can easily spiral into destructive interpersonal attacks that interfere with productivity. Diversity enhances performance only when the group flow factors are present. . . . (p. 71)
>
> The reason groups are so effective at generating innovation is that they bring together far more concepts and bodies of knowledge than any one person can. Group genius can happen only if the brains in the team don't contain all the same stuff. (pp. 71-72)

He adds that groups that work best are groups designed for the task at hand – the right number with the right mix of backgrounds, preferably with a facilitator and a group reward system, with a task that is appropriate for a group.

Sawyer next goes on to observe that the greater amount of interpreting and explaining required of people in a more diverse group enhances the generation of creative ideas:

". . . conversation is the source of the mind's concepts." (p. 131)

". . . group flow during . . . conversation . . . neither . . . started the discussion with a preconceived idea, and neither attempted to drive the flow of the conversation." (p. 138)

". . . the engine that drives collaboration is conversation. . . ." (p. 140)

"The most creative conversations are like improvisational theater dialogues; each speaker reinterprets what was said before and builds on it in a new direction so that unexpected creativity emerges from the group." (p. 142)

"Ideas that open possibilities, . . . called *equivocality*, contribute to innovation by making it easier for ideas to be reused to solve a different and unexpected problem somewhere else in the organization." (p. 145)

"An organizational culture that fosters equivocality, improvised innovation, and constant conversation – that's a recipe for group genius." (p. 149)

Sawyer's "Ten Secrets of Collaborative Organization" are as follows:

1) "Keep many irons in the fire." ["When the business environment changes, the best-selling product might become obsolete, but one of the back-burner ideas may suddenly emergy as the next new thing." (p. 162)]

2) "Create a department of surprise." [". . . because we won't have the successes without the failures, we need to create organizational cultures that cherish failures. . . . Even the projects that fail result in powerful knowledge that can potentially be used in a later project." (p. 164)]

3) "Build spaces for creative conversation." ["Open spaces feed into the natural flow of collaborative innovation – helping ideas to move from one area to another, allowing spontaneous conversations to emerge, and strengthening informal information-sharing networks." (p. 165) Workplaces can now be designed to "balance the power of collaboration with the need for private concentration time." (p. 166)]

4) "Allow time for ideas to emerge." [Pressure "makes people work harder, but it makes them less creative. . . . Low-pressure situations allow for collaborative conversations to unfold, and that's where innovations emerge" (p. 166)

5) "Manage the risks of improvisation." [The risks are a) time taken away from planned projects, b) difficulty to "sustain a central vision and a long-term strategy," c) too many new ideas that dilute resources and may not mesh together. ". . . create just the right balance of planning and improvisation." (p. 167)]

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Collaboration

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6) "Improvise at the edge of chaos." [". . . the critical balance for innovation is .. . . not to be rigid to prevent emergent innovation, but not too loose to result in total chaos." (p. 166)]

7) "Manage knowledge for innovation." ["The collaborative organization excels at transferring to other groups the ideas that emerge from good improvisations." (p. 170)]

8) "Build dense networks." ["When information is shared through collaboration, and decision making is decentralized, there's no need for a hierarchy to gather and channel information to a single decision maker. . . ." (p. 173)]

9) "Ditch the organizational chart." [Formalized organizational structures inhibit innovation.]

10) "Measure the right things." [Standard measures like traditional R&D or number of patents don't correlate with either profits or innovation. "Innovation is driven by representation of knowledge that can be reinterpreted and reused in new contexts, and by tools that allow access to that information in flexible and unexpected ways." (p. 177) "First, count the proportion of time spent on small exploratory projects; more is better, up to about 20 percent of total staff time. . . . Second, measure the average length of a project before being terminated (shorter is better). . . . Third, examine how well the organization celebrates and rewards failures. In short: Fail often, fail early, fail gloriously." (p. 178)]

Beyond collaboration within organizations and companies, Sawyer also points up the need for collaboration *among* them. To illustrate this, he notes that IBM's attempt to control the Token Ring computer network standard allowed the greater adoption of Ethernet, which was technically inferior until Cisco improved it. After their first demonstration of human flight, the Wright Brothers' subsequent attempt to control the future evolution of flight technology would have stifled it; only the efforts of Glenn Curtis and others to make further advances, such as wheels and ailerons, enabled the development of aircraft technology in the U.S. to keep up with advances in Europe. Similarly, SONY's Betamax video recording technology lost out to VHS, because JVC openly shared its VHS technology while SONY sought to control Betamax.

At all levels, Sawyer's message is that creativity is not the province of special geniuses, nor is it the product of lone geniuses. It comes from the collaboration of people.

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Nor will reduced runoff and rising seas be the only factors resulting from increased atmospheric carbon dioxide affecting our agricultural output. While the world's 130-day grain reserve in 1986 has already shrunk to a 40-day reserve in 2008, the following additional deleterious effects on agriculture are also expected: less nutritious wheat (resulting from the higher carbon dioxide concentration), lower yields (due to higher temperatures, and increased precipitation in "extreme events" separated by longer dry spells), water shortages (70% of the world's fresh water is used to irrigate production of 40% of the world's food), and greater agricultural destruction by insects. McKibben recognizes that "The Green Revolution lured us into a kind of ecological debt we're only beginning to comprehend." (p. 159) A Calorie of oil which once produced 2.3 Calories of food now produces only 0.1 Calories of food. Fertilizing soil with manure instead of chemical fertilizers requires restructuring farms to contain their own sources of manure. This and other practices using biological agents and products rather than chemical pesticides and fertilizers is the key to future agricultural productivity on Eaarth, McKibben emphasizes, and he recognizes that these practices will require more human labor.

It's a combination of "going not just green but *local*," McKibben writes (p. 187), and this applies to energy as well as food. The first step dealing with energy should be conservation, to which he would add heat from solar and biomass and electricity from wind and photovoltaics. Added are local jobs and savings from the cost of transportation of goods and transmission of electricity. McKibben notes that the Institute for Local Self-Reliance concluded that half the American states could meet their energy needs within their borders and that most could meet a "significant percentage" (p. 188) – *e.g.,* 81% in New York, two thirds in Ohio – and sees the formation of energy cooperatives similar to agricultural co-ops. "My point throughout this book has been that we'll need to change to cope with the new Eaarth we've created. We'll need chief among all things to get smaller and less centralized, to focus not on growth but on maintenance, on a controlled decline from the perilous heights to which we've climbed." (p. 204)

Although planet Eaarth will require a more local focus to our lives, McKibben would retain the wider vistas experienced on the former planet Earth on the Internet, "which is why, if I had my finger on the switch, I'd keep the juice flowing to the Internet even if I had to turn off

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over, they observe that there is no evidence that foreign born STEM workers have repressed wage increases for U.S. STEM workers. Additionally, increased rates of U.S. patenting by foreign born workers show that they are making greater contributions to technological innovation. Immigrants are also responsible for 15 to 26% of new companies in the tech sector.

But it remains a question whether foreign students will continue to be attracted to come to the U.S. to earn a degree and join our STEM workforce, especially as China and India seek to develop their own strong university system. ". . . if we wish to outpace other nations in innovation-based economic activities and the high paying jobs that these provide and enable, the important task is to increase global demand for U.S. STEM workers and their products," Atkinson and Mayo observe. To do this, they say, we need a "top-down strategy wherein the United States commits to regaining global innovation leadership" and "bottom-up strategy in which we consciously create a generation of STEM workers that has a much larger fraction of innovators, who can create jobs and products at an even faster pace. The latter — alongside a STEM workforce system that produces individual workers in the right numbers, with the right skills, at the right times, to keep a high-pitched innovation economy humming — *are the foci of this report*." (p. 36) (emphasis added)

But this is not to argue against training more U.S. STEM workers, Atkinson and Mayo point out. "U.S. STEM jobs are growing but foreign workers are filling some of them. We could capture these jobs for American workers if enough American workers gained the skills needed for these jobs and wanted to work in them. That is *what the remainder of this report is about*." (p. 39) (emphasis added)

Atkinson and Mayo also contrast working as part of the STEM workforce with employment as a doctor or lawyer (p. 37). While STEM wage increases were comparable to those for workers in other sectors of the U.S. economy between 1999 and 2009, those for doctors and lawyers were greater. This is presumably because STEM and other workers can be obtained in the global marketplace, while licensure requirements limit doctors and lawyers to the American marketplace. Elsewhere (p. 140) the authors note that, because their services are always needed, the employment of doctors and lawyers is not subject to economic downturns which affect tech industries.

"All STEM for Some"

The approach to attract more Americans to become STEM workers advocated by *Rising Above the Gathering Storm* and PCAST's *Prepare and Inspire* report, both covered on the front page of our Fall 2010 issue, is characterized by Atkinson and Mayo as "Some STEM for All." Their description of its central tenet is that "we can increase the quantity of STEM workers by reaching out to more students, more often, and with higher quality STEM education . . . to make sure that every high school graduate and a much larger share of college grads become proficient in STEM . . . [by] boosting K-12 teacher quality . . . more rigorous STEM standards . . . improving curriculum, and boosting awareness among students of the importance and attractiveness of STEM careers." (p. 43) They also note that proponents of "Some STEM for All" cite the need to enable underrepresented groups in the STEM workforce to experience STEM and its employment benefits and also enjoy the greater participation in American society that comes with science literacy.

Atkinson and Mayo disagree with the "Some STEM for All" approach. They cite it as an application of the leaky STEM pipeline model, by which Norm Augustine calculates that the probability that an entering student will emerge with a STEM PhD is one in three hundred. The "leaky STEM pipeline model is problematic . . . because it suggests that the central problem is one of sheer quantity of inputs," they write, adding that ". . . a second problem [is that] . . . even if the 'fill the pipe' model were successful, it requires a tremendous amount of resources to keep the pipe full." (p. 44) They argue that the investment required to implement "Some STEM for All" is not likely to be forthcoming and call upon educational institutions to "adopt more effective and enlightened approaches." One reason they claim that "Some STEM for All" is inappropriate is that only 5% of all jobs relate to STEM. Moreover, "Not everyone is interested in STEM, no matter how attractive the field is. Not everyone has the capability to get a STEM degree, no matter how good their teachers are or how many STEM courses they are required to take." (p. 45)

Instead of "Some STEM for All," Atkinson and Mayo propose "All STEM for Some":

> This "All STEM for Some" approach is far more cost effective than "Some STEM for All" because of the smaller number of individuals involved. Getting 5 percent of the workforce to be STEM-proficient does not require STEM education for everyone, everywhere, all the time. Focusing on fewer individuals allows the luxury of building a "new

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> and improved" pipeline that emphasizes mass customization of content, development of innovation-era (rather than production-era) skill sets, and frequent industry engagement with the application and practice of those skills. (p. 48)

Moreover, specialized science schools, if they offer their opportunities to all, can draw underrepresented groups under the rubric of "All STEM for Some" more effectively than "Some STEM for All."

Atkinson and Mayo then proceed to argue against several premises underlying "Some STEM for All":

"Efforts to Increase Teacher Quality do not Make a Significant Difference in the Production of STEM-Ready Students." Citing the *2010 Science and Engineering Indicators*, Atkinson and Mayo state that "The pedagogical skill of the instructor is widely believed to be the key determining factor in student success both within and without STEM fields." (p. 51) Then they cite another analysis that only 3% of teacher performance can be attributed to measurable quantitative data (*e.g.*, experience, education level, standardized test scores). They next address subject-matter expertise, evaluated in terms of advanced degrees and whether they are "in field," and cite research showing little correlation between teachers' advanced degrees and student test scores except for middle school math. "In the end, we must recognize that teacher qualifications are not a substitute for teacher quality. Solutions that call for higher education levels of teachers underestimate the cost-to-benefit ratio of such programs," they conclude, adding that "a much more effective and vastly cheaper strategy is to match high-quality STEM educators with a relatively modest number of students who are most likely to be interested in STEM. If this is the strategy pursued, there is clearly no shortage of highly qualified STEM educators in the nation." (p. 53)

"Increasing Teacher Pay Does Not Increase STEM Teacher Quality." Here Atkinson and Mayo cite a Raytheon modeling study: ". . . increasing teacher pay does not result in better teachers . . . an increase in teacher pay increases the candidate pool . . . [this] would improve teacher quality if school administrators hired the more capable new teachers from the larger pool of candidates, but there is an absence of data to support a conclusion that this will happen." (p. 53) The Raytheon study continued that industry would then counter the increased teacher salaries by higher salaries in industry, thus negating the effect of the teacher salary increase. At the same time, Atkinson and Mayo cite the importance of such factors as administrative support, collegiality, curricular autonomy, and access to lab equipment in offsetting lower salaries in attracting and retaining high quality teachers, noting that these factors enabled private schools to attract teachers at $39,690 per year while public schools paid annual salaries averaging $52,230.

"A National Curriculum and/or National Standards in STEM are Unlikely to Improve the STEM Talent Pool." With support like that of the National Science Board's *National Action Plan* and leadership of the National Governors' Association and the Council of Chief State School Officers, the Common Core State Standards Curriculum is being developed to increase the number of students knowledgeable about STEM. The response of Atkinson and Mayo is that "Education reform experts Ted Kolderie and Tim McDonald [editors of another ITIF publication] describe this standards-based model as batch processing, where batches of students are all provided . . . the same education." (p. 56) This has the effect of denying students the opportunity to pursue their academic passions and can alienate them from school, according to Atkinson and Mayo: "Instead of innovating to find new approaches, we try to improve performance by pushing ever harder to standardize and test." (p. 58)

"Prior Attempts at Standardization Have Not Yielded Significant Improvement in Learning Outcomes." One example of a standardized approach to education has been No Child Left Behind (NCLB), and Atkinson and Mayo show that that the National Assessment of Educational Progress (NAEP) scores showed more improvement in the pre-NCLB 1999-2004 period than in 2004-2008. "At best," they write, "NCLB seems to help some age-levels in some subjects; at worst, it has no benefit at all overall. . . . standards-based reform is neither a reliable nor cost effective approach to correcting educational inequalities, nor does it succeed in promoting needed STEM education excellence." (p. 59)

Atkinson and Mayo conclude that "while 'Some STEM for All' is a worthy goal, 'All STEM for Some' is a far more achievable goal, and the one immediately necessary for the creation of our next generation of technology innovators." (p. 60)

Test for Skills Instead of Facts

In addition to replacing "Some STEM for All" with "All STEM for Some," Atkinson and Mayo would also reform the STEM curriculum – by focusing on STEM skills rather than on STEM facts. Traditional education,

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they observe, is based on books because it was begun when books were rare; it focused on what students learned rather than on what they were able to do. "Knowledge . . . is now all around us," Atkinson and Mayo write, "thanks to the Internet . . . it will be skills – or the ability to use, manipulate, and apply that knowledge that will differentiate high-performing nations from the rest." (p. 64) They cite the work of the Partnership for 21st Century Skills (critical thinking, problem solving, creativity, innovation, communication, and collaboration, according to the article in our Winter/Spring 2009 issue) and nine fundamental skills recognized by ACT as the result of their investigating skill requirements of 16,000 different jobs: 1) reading for information, 2) locating information, 3) applied mathematics, 4) teamwork, 5) observation, 6) listening, 7) (business) writing, 8) workplace observation, and 9) applied technology. (Skills #1-3 are classified as "foundational" or "learn to learn," #4-9 as "personal"; the foundational skills can be evaluated by ACT's WorkKeys tests.)

Because the ACT fundamental skills cut across all disciplines, students can develop them no matter what courses they take. Atkinson and Mayo would replace subject-matter standardized tests by skills-based tests, although conceptual learning would still be assessed by teachers in their classrooms, and STEM would require additional skills – inquiry (for science), design (for technology and engineering), and facility with symbolic language (for math). They liken knowledge to the content on a roadmap. The skill comes in knowing how to read the map/apply the knowledge. They envision a rich set of electives from which students can develop STEM-specific skills.

Atkinson and Mayo recommend testing with concept inventories and particularly cite Richard Hake's 1998 analysis of pre- and post-scores on the Force Concepts Inventory from 6542 students, which showed "that interactive learning approaches are almost twice as effective as lecture." (p. 73) This is the basis for their advocacy of interactive approaches to learning and writing that "two promising interactive approaches are project-based learning and game-based learning." (p. 69) "The premise underlying project-based learning is that challenging real-world problems can sustain students' interest and stimulate critical thinking as they acquire and apply their knowledge . . . If the project is rich and well-designed, students can delve far more deeply into a subject than

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Resources for Project Based Learning

As indicated by "The Emerging Generics of an STS Module" in our Fall 1992 issue, using critical thinking to collaborate with others to develop and communicate solutions to practical problems has long been the *raison d'être* for the science, technology, and society approach to education. This underlying concept in education has now broadened into the genre of Project Based Learning (PBL), and the Buck Institute for Education has taken leadership in developing it with Project Based Learning for the 21st Century, accessible online at <www.bie.org>.

At the Buck Institute's website you will find explanations of PBL and reasons to use it, in both written and video format. The Buck Institute characterizes PBL by seven basic elements: 1) an open-ended driving question or challenge; 2) a need to know essential content and skills; 3) inquiry to learn and/or create something new; 4) critical thinking, problem solving, collaboration, and various forms of communication ("21st century skills"); 5) student voice and choice; 6) feedback and revision; and 7) a publicly presented product or performance.

The Buck Institute also provides links to 438 different projects that have been developed by a variety of groups and organizations. They address just about all education disciplines, but most of them address the Arts (88), English Language Arts (114), Math (139), Science (122), and Social Studies (144). The reason that the numbers in parentheses add to more than 438 is that many projects are interdisciplinary. You can also purchase the *PBL Starter Kit* (for $424) or the *PBL Handbook* (for $35). Or, as was mentioned in our earlier article back in Fall 1992, you can develop your own project. Here the website, <pbl-online.org>, provided by the Buck Institute and Boise State University Department of Educational Technology, offers a framework embedded in the principles of Wiggins and McTighe's *Understanding by Design*. Its first Design Principle is to "Begin with the End in Mind," followed by "Craft the Driving Question," "Plan the Assessment," "Map the Project," and, finally, "Manage the Process." Another website endorsing PBL comes from George Lukas's *Edutopia*: <www.edutopia.org/project-based learning>.

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traditional textbook-oriented instruction permits." (p. 69) Examples of research showing the efficacy of project-based learning in England and Israel are cited. In addition to enhancing learning, Atkinson and Mayo point out that videogames also provide information when it is needed and in context as well as embodying "a high feedback frequency to the user, explicit goals, embedded reward systems, hierarchically tailored difficulty, multimodal engagement . . ., user control over navigation . . . and more." (p. 74)

At the college level, Atkinson and Mayo note that the biggest hindrance to interactive STEM learning is "low cost mass lecture classes in a student's early years to offset the otherwise prohibitive price point of small laboratory classes in later years" (p. 75), although they note some institutions trying to break from this model to more interactive learning. They cite the National Survey of Student Engagement for institutions subscribing to it, but lament that very few publish their scores and recommend that it be required on federal grant applications and included in *US News & World Report* rankings. Were colleges to engage students in more interactive learning, future K-12 teachers would be exposed to the kind of teaching they should do in their classrooms.

Fewer Requirements, More Electives

If assessment is to be shifted from facts to skills, Atkinson and Mayo next observe that "If K–12 graduation requirements focus on just the six to eight core skills, then high schools should be able to produce 'generic' high-quality employees by graduation, while minimizing required courses along the way. This then opens up opportunities for deep divers and those passionate about a subject, to explore it more fully in high school. Long sequences of courses in one topic become possible. So do courses that reflect unusual combinations of interests. Driving this new era of skills-centric learning in high school would enable high schools to become a system of mass customization, rather than one of mass production." (p. 79)

Whether a course should continue to be required could be determined by how well it increases core skills, according to tests (which are already available for the ACT "learn to learn" skills). "The 'Learn to Learn' skills, once taught well, eliminate the need to require most knowledge-centric courses." (p. 80) "At most, one high school science class should be required for graduation, with no restriction on which one." (p. 81) Reducing the number of required STEM courses would also free students to learn other STEM topics. "How ironic that engineering and IT together employ 80 percent of STEM workers, yet are nowhere represented in the K-12 curriculum," Atkinson and Mayo muse. (p. 81)

The need for math requirements would be greater than for science, however, because math "is far more central to more occupations" and "also builds linearly on itself in such a way that missing one year early on handicaps the student into the future." (p. 82) Because of their widespread use (and being, along with computational math, the only aspects of math ACT tests in their WorkKeys test for the applied mathematics skill), only algebra, geometry, and statistics are recommended to be required. Because calculus is not widely used and is also offered to college freshmen who need it, deferring it until then "opens up the opportunity for STEM students to take advanced statistics or computer science instead." (p. 81) Although precalculus/trigonometry is "not really necessary as a core workforce skill, eliminating it as a graduation requirement will add an extra year or an extra summer to a non-STEM major who wishes to turn into a STEM major in college." (p. 81)

Another way to free students to take more elective courses to pursue their passions is to incentivize them to obtain credit for required courses "through proficiency rather than seat time." (p. 82) Along these lines Atkinson and Mayo cite a "self-paced, Internet-based program of study" offered to at-risk students in two Colorado counties which grants a high-school diploma upon passing "nine WorkKeys . . . with scores equivalent to those of a beginning college student . . . [and] has resulted in an 80 percent graduation rate." (p. 83)

Bringing STEM Courses to Students and Students to STEM Courses

Once students are freed from course requirements, the courses that interest them must be made available. In the case of STEM, two strategies are high schools specializing in STEM and K-12/community college partnerships. There are now about 100 STEM high schools in the U.S., and they have been both effective and cost-effective in bringing STEM to interested students. Their graduates are more likely to enter college, complete their bachelor's degree in four years, and earn a post-graduate degree.

STEM schools are one aspect of the British system of specialized high schools, formulated as their solution to paying for technology education without having to pay to equip all schools with computers. Specialized schools

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can be more attractive to corporate support, as has been the case with Thomas Jefferson High School in Alexandria, VA. A variation of the STEM school is the STEM-focused "career academy" within an existing school.

The success of STEM schools requires attracting all students interested in STEM to them, and this means a successful recruiting program. In fact, this is only the first step in what Atkinson and Mayo envision as a STEM recruiting program throughout the educational system, and they liken the needed intensity and thoroughness to the nature of recruiting practiced by the NCAA for basketball players. They also recommend a fivefold multiplication in the number of STEM high schools over the next ten years, with half the $10 million/school recommended by PCAST's *Prepare and Inspire* (covered in our Fall 2010 issue). The resulting 500 STEM high schools could accommodate a third of the nation's needed STEM workers.

"Early College High School [resulting from K-12/community college partnerships] now operates in 200 schools in 24 states." (p. 86) It allows students to earn an A.A. along with a high school diploma – a boon to low-income students for whom college tuition is an economic barrier.

But as attractive as these options may be for delivering a richer variety of STEM courses, they can't compare with the opportunities now available from online learning, "the easiest way to reach large numbers of students who are geographically dispersed." (p. 87) Atkinson and Mayo observe that 45 states have "some form of state-funded online learning," 27 have "full-time online/virtual schools . . . and 25 states allow enrollment in full-time virtual programs." (p. 87) ". . . because 40 percent of our nation's high schools do not offer Advanced Placement, 50 percent of the online courses offered in high schools are AP and dual-enrollment classes." (p. 87) The NSF-funded iLabs project allows students to perform experiments using "web-networked scientific tools." (p. 88) "In K–12, Florida Virtual School (FLVS) students outperform bricks and mortar school students by about 39 percent across the sixth-grade to tenth-grade state math exams. Even better results are achieved for reading." (p. 88) Because they allow students flexible use of time, "virtual schools provide a student-centered experience," and teachers serve as facilitators rather than as lecturers.

In addition to reaching students regardless of their location in space and affording them complete flexibility in their use of time, from "data from assessments, assignments, presentations, projects and tests . . . teachers . . . can reconstruct not only what students know, but the pathway by which they came to know it . . . . In the future, mass customization and increased personalization in online learning will be facilitated as artificial intelligence supports advances in adaptive content and adaptive assessments, and recommendation engines funnel student learning preferences into learning contexts that are most relevant with customized content. Ultimately, each module of information will be deliverable in multiple formats and platforms, each tailored to best meet the needs of a particular student at a point in time." (p. 89)

A variation of online learning is "blended" or hybrid learning, which combines online and face-to-face, with between 30% and 79% online. The "buffet model" delivers some courses traditionally, others online, while the "emporium model" delivers all courses as a combination of the two. Atkinson and Mayo report that the cost of virtual schooling is 85% that of bricks-and-mortar schooling.

Fostering Interdisciplinarity

While Atkinson and Mayo lament that breadth requirements at the high school level have precluded in-depth studies, they lament that at the college level depth requirements preclude interdisciplinary connections. Whereas they would like to cultivate what they call "deep divers" at the high school level, in college they would like to cultivate what they call "interdisciplinary connectors" as a means to advance innovation. Their reason for this is "Fleming's study of 17,000 patents" that showed that "multidisciplinary teams generate patents with a wider spread of success rates than homogenous teams." (p. 93) They also note that graduates of interdisciplinary science programs have found higher pay and better employment prospects and that these programs have been particularly attractive to women. But interdisciplinary learning is "nowhere near[ly] as prevalent as it could be[,] in part because of divergence between faculty incentives and student interests." (p. 94)

"Federal research funding [second only to student tuition as an income source] . . . and published rankings" serve to reinforce the existing disciplinary system, and Atkinson and Mayo recommend dismantling it. They observe that peer review panels are prone to favor proposals from institutions like their own, and, in effect, this amounts to an "old boys network" preserving the *status quo*. To make federal research funding a more inclusive process, they recommend that research proposals be

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evaluated solely on the merits of the proposed research and the citation frequency of the applicant's prior work, not by the applicant's name and reputation, and that peer review panel membership be diversified by adding representatives of other fields, types of institutions, and industry (either active or retired), so that no more than a third are from the same field or type of institution as the applicant. This would also require applicants to explain their research to a wider audience. And for grants requiring matching funds, provision of these funds from industry would indicate that the research proposal has been viewed as having merit in the marketplace. ". . . most of the[se] suggestions are designed to prevent reviewers from judging the perceived merits of proposed work by extrapolating from the researcher's history outside of the grant proposal." (p. 99)

If Atkinson and Mayo had their say with college rankings, they would replace the National Research Council's *Assessment of Research Doctoral Programs* and the *US News & World Report* rankings with "a new industry-based ranking system" that "would express the desirability of a department's graduates as potential employees." (p. 101) An industry-led organization concerned with STEM workforce issues, such as the Industrial Research Institute or the Business-Higher Education Forum" should generate the rubric for evaluating departments, and a philanthropic organization should fund a "neutral survey research company" to implement it. ". . . an industry-generated ranking of universities should help close the skill gaps between students' training and employer needs, thereby also reducing spot shortages in STEM fields." (p. 101)

The model institution that Atkinson and Mayo cite for STEM education at the college level is the Olin College of Engineering (Needham, MA), chartered in 1997, admitting 85 students per year since 2002, with free tuition until 2009 and now paying half tuition, to meet the "increasingly global and collaborative nature of engineering solutions." (p. 102) Although Olin awards engineering degrees in various areas, it has no departments and no faculty tenure. Its students are selected from "Candidates" who participate in design projects and tem exercises on a "Candidates' Weekend." Females comprise 44% of its student body, and minorities 17%.

Olin's curriculum consists of six elements: mathematics, science, engineering science, design, context, and personal interest, thus adding "teamwork, project-based learning, entrepreneurial thinking, and communications skills to engineering curricula, as well as a greater emphasis on social needs and human factors in engineering design." (p. 102) While other schools are reluctant to publish their National Survey of Student Engagement ratings, Olin publishes them with pride, because they are way off the chart.

Lest one conclude that Olin's approach to engineering is an isolated success, Atkinson and Mayo also report efforts to institute an Olin-like program for 80 freshmen at the University of Illinois (Champaign-Urbana) in 2009. So far these have been successful, and there are plans to expand the program to 3000 freshmen in 2010. Noting that creating more student demand for an Olin-type experience will persuade other schools to adopt Olin's approach, Atkinson and Mayo suggest ways to make "Transformation institution" grants under NSF's Advance program more efficacious.

Promoting Entrepreneurship

Keeping their eye on the central importance of innovation in their report, Atkinson and Mayo see innovation as coming from explorations in "uncharted territory" and "heretofore unexplored areas," resulting in a concept that can be turned into a tangible product or service. This, they note, is the first of the two-step process of entrepreneurship. Business schools teach the second step, which is to market the product, but the first step falls under the purview of engineering design, which most courses don't interface with market reality, to the dismay of Atkinson and Mayo. "So, business majors lack engineering design, engineering majors lack market context, and science majors lack both." (p. 107) The prescription from Atkinson and Mayo to overcome this problem is courses in "Real Design by Real Teams for Real Customers." (p. 107)

They observe that two institutions doing entrepreneurship training right are MIT (nearly a quarter of whose graduates become entrepreneurs, but less than 4% of them under age 23) and Olin College (10% of whose alums since 2006 have already become entrepreneurs). Both institutions stand apart in "offering their students experience in creating a 'real product'. . . ." (p. 108) To incentivize more institutions to offer "Real Design by Real Teams for Real Customers," Atkinson and Mayo reiterate their proposals to rank universities "according to the quality of their students as perceived by industry" and "removing incentives for faculty to remain in disciplinary silos." (p. 100) They also propose involving faculty with industry so that the faculty will "engage graduate students more systematically with industry." (p. 109) The beneficial value of interaction with industry is seen in the

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operation of NSF's 54 Industry University Cooperative Research Centers, which are 81% funded by industry. These centers, with annual government funding of $5 to $7 million, have produced at least one spinoff per year, at a lower cost per spinoff than those coming from the 15 Engineering Research Centers with their $40 million annual budget (all funded by the government).

According to Atkinson and Mayo, the three big barriers to technological entrepreneurship are 1) "willingness to take [personal financial] risks" ("the tech entrepreneur wants to amass enough savings before quitting a job"); 2) "access to capital" ("the tech entrepreneur uses personal savings to finance company startup"); 3) "business acumen" ("the tech entrepreneur works in another company long enough to understand 'how business works'") Of these, access to capital is believed to be the most responsible for the time a would-be entrepreneur spends as an employee before starting a company (software companies, with lower capitalization, are launched earlier in entrepreneur's lives). Atkinson and Mayo propose three ways to enable students to go seamlessly from school to entrepreneurship:

1) Allow "entrepreneurial leave" for students to leave school to start up a company and return if the company fails. This is especially important, they note, for foreign students, which, among MIT alumni, form companies at a higher rate than domestic students.

2) Allow the Small Business Innovation Research (SBIR) program to find student startup companies (for students who have a bachelor's degree, which "appears to be a minimum for successful company formation" (p. 112))

3) Require an experienced entrepreneur on the management team for all SBIR ventures.

Strengthening the STEM Workforce

Atkinson and Mayo conclude their report by addressing the foci of their report: "a STEM workforce system that produces individual workers in the right numbers, with the right skills, at the right times, to keep a high-pitched innovation economy humming."

Should the current supply of foreign STEM workers not be available, the domestic supply of STEM workers

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STEM Entrepreneurship

In their report, *Refueling the U.S. Innovation Economy: Fresh Approaches to STEM Education*, Robert Atkinson and Merrilea Mayo espouse the cause of entrepreneurship growing from STEM fields. This *Newsletter* has reported on the work of many such entrepreneurs, two of them founding the Terracycle Company while they were still students at Princeton University, as reported in our Spring 2008 issue (so much for Atkinson and Mayo's statement that a bachelor's degree "appears to be a minimum for successful company formation").

Other STEM entrepreneurs are reported on in this issue. Two days before she spoke to the Physics Club of New York about her quantum cascade lasers (see story on p. 14 of this issue), Claire Gmachl received a $500,000 grant from the Schmidt Fund (endowed by Google CEO Eric Schmidt and his wife Wendy) at Princeton University to pursue the development of a quantum cascade laser that would enable diabetics to read their blood sugar level noninvasively. According to the *Princeton Alumni Weekly* for 19 January 2011, Gmachl's was one of two proposals funded of 47 submitted. The Schmidt fund is designed to support "work still in its early stages . . . not [yet] . . . a good candidate for federal funding or support from an industry partner." Still another STEM entrepreneur whose work is profiled in this issue (p. 20) is Micromidas founder Ryan Smith, ready to scale up his process of manufacturing biodegradable plastic from wastewater solids.

Furthermore, the 10 April 2011 issue of *The Times of Trenton* describes other STEM entrepreneurs who "pitched" their products at Princeton University's Keller Center for Engineering Innovation Forum. The winning entrepreneur was Christian Theriault, whose "adaptive optics technology could find migrating cancer cells, quickly scan an airport for security threats, and speed up laser manufacturing by an order of magnitude." The second prize went to two graduate students, Yife Huang and Sushobhan Avasthi, and a professor, James Sturm, for "a new way of manufacturing photovoltaic cells" that could reduce the time needed to make solar photovoltaics competitive with other electricity sources from ten years to three. Third prize went to graduate student Vikram Pansare and professor Robert Prud'homme for developing "a bioimaging dye that can improve the accuracy of sur-

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would need to increase by 20 to 30%, they note. This could be achieved by reducing the number of college freshmen declaring STEM majors who drop out or switch to another major. More than two thirds of the dropping out and switching occurs between the freshman and sophomore year, with dropping out at rates that are lower than in non-STEM fields but switching at rates that are higher. "If we could eliminate switch out that first critical year, we could potentially increase the number of STEM graduates by 20 percent or more." (p. 123)

Although the median grade in STEM courses is typically lower than in non-STEM courses (Atkinson and Mayo cite College Board data showing 85% of students in English classes receiving A or B, but only 60% in history classes and 57% in math classes), the more typical reason for students to switch from majoring in STEM is poor pedagogical experience, which thus turns out to be a "gate" in the production of B.S. recipients which "achieves a reduction in quantity with no increase in talent." (p. 124) (Atkinson and Mayo cite two studies to show that those dropping out of STEM and those remaining have comparable GPAs; "the only singular difference was that the 'persistors' had a greater willingness or ability to 'put up with' the poor learning environment." (p. 124))

Atkinson and Mayo state that switching out of STEM after the freshman year can be reduced by moving more interesting experiences into the freshman year – *e.g.,* engineering design courses (already demonstrated at the University of Cincinnati and Alabama A&M) and participation in original research. They recognize, though, that such institutional reform will not be easy, because institutions are already set up to accommodate the present rates of switching and dropping out. "It is in America's interest to produce more STEM graduates, while most universities and colleges are largely indifferent to the issue of what people major in." (p. 126), and it is in this sense that Atkinson and Mayo cite a study by Paul Romer which describes undergraduate institutions as "a critical bottleneck in the training of scientists and engineers" (p. 115) They counter by proposing that ". . . the best way to promote retention [of STEM majors] reform is not to ask institutions to reform . . . but to reward major gambles by institutions that have taken transformative steps and succeeded." (p. 127)

At the graduate level, Atkinson and Mayo observe that the salary gap between holders of STEM master's and doctor's degrees has narrowed considerably in the past 13 years. "The primary 'gates' for STEM master's degrees appear to be insufficient programs designed with industry (as opposed to the academic-track master's) and insufficient transparency to allow industry to find, recognize, and hire students coming out of industry-oriented programs." (p. 129) These "gates" have been addressed by the professional science master's (PSM) degree, which blends science and business courses in a 70/30 ratio. PSM graduates command higher salaries than those with traditional master's degrees, and this success meshes with Romer's description of traditional graduate students as "trained only for employment in academic institutions as a side effect of the production of basic research results." (p. 115) Although there are still only 2600 students in 195 PSM programs at 96 institutions, they draw a higher percentage of women and underrepresented minorities than do traditional master's programs.

Matching STEM Worker Qualifications and Requirements

More important than producing more STEM workers is to produce them in fields where shortages are expected, which is now the case in computer science, Atkinson and Mayo state. ". . . IT jobs grew more than four times as fast as all U.S. jobs between 1999 and 2008," and 1.5 million more IT jobs are expected to open up in the next decade, much more than the number of earned degrees in the field. But while computers have revolutionized inno-

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STEM Entrepreneurship

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gical procedures, aid in medical diagnosis, and make drug trials more effective."

According to the 13 April 2011 issue of *U.S.1*,Theriault's technology "uses sound to change the properties of light" to give a "lens the ability to rapidly change focal lengths and resolution." Theriault and Princeton Professor Craig Arnold have founded TAG Optics to develop their technology. Huang, Avasthi, and Sturm's new approach to manufacturing photovoltaic cells is to reduce the amount of silicon needed by coating the silicon with organic materials that require less money and less energy and can tolerate a less clean environment in their manufacture. They have founded SuryaTech to develop their technology. The first prize winner received $25,000; the second $10,000; and the third $5000.

(*Editor's Note*: *U.S.1* also observes that it was at the 2002 Forum that then Princeton freshman Tom Szaky got his start in founding Terracycle.)

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vation in just about every aspect of our lives, the number of K-12 computer science courses (many of them teaching only computer programming) and students taking them has not kept pace.

One reason that computer science education, K-12, has not kept pace with the demand for IT workers, as Atkinson and Mayo see it, is the emphasis on English, math, and science by NCLB and the Common Core State Standards Initiative. Moreover, the use of computer technology in core courses and the development of IT literacy is not the same as computer science education, "which differs from basic technology literacy/IT goals in that it teaches fundamental concepts of computing, rather than its use via applications." (p. 121) (Atkinson and Mayo define "computer science" as "an academic discipline focused on the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society." (p. 121) They are also critical of the present system of certifying computer science teachers and the inadequate number of teachers so certified.)

Until Atkinson and Mayo can achieve their program of replacing content standards by skill standards and thereby reduce the number of required courses, their recommendation to insure that K-12 students receive computer science education is to define computer science as a core subject. Their answer to their question of why "we still have so little K-12 capacity in computer science, after a decade of needing millions of computer scientists in the workforce" (p. 122) is that, since schools are conservative, "introducing new curriculum is not the norm. In addition, we did not make the leap from workforce needs to computer science instruction because it was no one's job to scan for major occupational shifts, and then link those to educational reforms." (p. 122) This could be remedied, they go on, by requesting the U.S. Department of Labor to notify the Office of Science and Technology Policy (White House), Congress, and the U.S. Department of Education "of any STEM field experiencing or about to experience a major expansion or contraction. . . ." (p. 122)

". . . the overall system of higher education in the United States is only moderately responsive to labor market signals," Atkinson and Mayo lament more generally. (p. 135) For this reason, they advocate that ". . . industry. . . needs to engage students directly. . . . Students who intimately understand what they will need to know on the job can choose more appropriate majors, select among course options more accurately, and demand new courses where none exist. In this manner industry can better apprise students of job needs in the marketplace." (p. 135) (Atkinson and Mayo also lament that press accounts of programming jobs shipped offshore can reduce the number of Americans pursuing programming careers and create shortages for defense contractors who must hire U.S. citizens as programmers.)

To foster communication between industry and students, Atkinson and Mayo advocate an NSF-industry fellowship; half-funded by industry, this program could support twice the number of current NSF fellows at the same cost. Other interactions between NSF and industry on behalf of NSF fellows would also enhance communication between industry and students, and such communication is important, because only 36% of STEM PhDs go into academia. This model could also be applied to the bachelor's or master's level by combining scholarship programs of federal agencies, professional societies, and trade organizations. Atkinson and Mayo also advocate internships and summer jobs in industry and suggest that employing college freshmen or sophomores in middle-level tech jobs (that can be easily learned by a high school graduate with a strong tech background) would give them exposure to technological systems that they might be stimulated to improve in later years of their STEM career.

Insuring that Qualified STEM Workers are Available when Needed

Not only must STEM workers with the right qualifications be available. They must also be available when they are needed. Given that business cycles are shorter than the time needed to educate a member of the technical workforce, even instituting the improved communication between students and industry that Atkinson and Mayo recommend may not allow students "to redirect their training fast enough to correspond to the pace at which world events can suddenly overwhelm [an] industry." (p. 140) An example is the dot.com boom of 1995-2000, which saw IT graduate rates static from 1991 to 1997, then increase to a peak of 60,000 in 2004, four years after the dot.com crash.

To insure that "every worker has a job and every job has a worker" (p. 141), Atkinson and Mayo recommend the following:

1) Indexing H-1B visa caps or visa fees to employment rates, in order to accommodate foreign STEM work-

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ers when they are needed for jobs. That their salaries have been greater than those of U.S. workers and that the pay differential has decreased with an increase in the number of visas shows that these workers compete with each other and are not cheap substitutes for U.S. workers.

2) Matching employers and employees by profiling jobs by skills, layering content knowledge tests over the WorkKeys skills tests (already used for non-STEM jobs and required for all youth in Wyoming, Illinois, Kentucky, and Michigan), as needed. By ascertaining skills improvement needed to qualify for a job, applicants can improve their job qualifications from training directly targeted to needed skill improvement, which can be obtained from publishers like Key Train and WIN more expeditiously than from further formal education.

3) "Banking" STEM workers not needed during an industry downturn by employing them at universities or government laboratories. A Dutch program requires industry to pay 10% of the salary of "furloughed" employees, with the government paying the rest. This keeps STEM workers in the STEM job pool and ready to return to industry when needed.

"The general consensus," Atkinson and Mayo write at the beginning of their report, is that "the last thing we need is another report," (p. 7), and on pages 14-19 they list "Half a Century of STEM Reports and Policy Recommendations," most advocating "Some STEM for All" and dating back to Vannevar Bush's *Science, the Endless Frontier* (1945). Rather, they say, "Now is a time for action." Action following their recommendations will revolutionize STEM education in the United States for many years to come. Their report is available online at <http://www.itif.org/files/2010-refueling-innovation-economy.pdf>.

Lipson

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reported that about 15,000 people are using it, including Citizen Science.

Although the data deluge accelerates our motivation to model, hypothesize, and test, Lipson noted that we ourselves must decide the variables we want in our models. Some are concerned, he cautioned, about the possible end of an era of analytical understanding.

Clearinghouse Update

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

The Trend to Electronic Journals

Our Spring 2008 issue contained articles about the trend to public online access of peer-reviewed scientific literature and how this can be reconciled with the cost of the peer-review process. Interviews by the New York Academy of Sciences with seven people involved with online publication of peer-reviewed scientific literature in the Spring 2010 issue of its *Magazine* indicate several new developments in this area.

The *Public Library of Science*, cofounded by Harold Varmus, publishes seven online journals, with the profits from five of them enabling free access to the other two – *PLoS Medicine* and *PLoS Biology*. The number of articles they report rejecting suggests that their journals have become highly respected, though perhaps not as much as *Nature*, *Cell*, and *Science*, which are "going to be the last to go completely open access." Moreover, open access to online publications democratizes the peer-review process by allowing all readers to become post-publication peer reviewers with the comments that they post. (Interestingly, this process of post-publication review has been the tradition for arts and literature for a long time running.)

Getting the Most Out of NSDL Science Literacy Maps

Digitized versions of the progression-of-understanding maps published in Project 2061's *Atlas of Science Literacy* have become a popular feature for searching and accessing teaching resources in the various collections of the National Science Digital Library. Now, with a new grant from the National Science Foundation, Project 2061 will be working with various NSDL entities to help increase and improve the use of the NSDL Science Literacy Maps as tools for understanding how K-12 students make progress in their science learning and the implications for selecting and using NSDL resources.

Beginning in January 2011, the two-year $510,000 grant will enable Project 2061 to conduct face-to-face workshops at national and regional science education conferences to help NSDL users understand and take advantage of all of the features of the Science Literacy Maps. A set of just-in-time online learning tools will also be developed and embedded in the maps themselves and made accessible through the NSDL *Pathways* that serve

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News from Triangle Coalition

NCES Releases PISA 2009 Results

The performance of U.S. 15-year-old students improved in science, regained lost ground in mathematics, and held steady in reading, according to the results of an international assessment released last week by the National Center for Education Statistics in the U.S. Department of Education. The report, "Highlights From PISA 2009: Performance of U. S. 15-Year-Old Students in Reading, Mathematics, and Science Literacy in an International Context," compares the performance of U.S. 15-year-old students in reading, mathematics, and science literacy to the performance of their peers internationally. PISA, or the Program for International Student Assessment, is designed to assess what students have learned -- both inside and outside of school -- as they near the end of compulsory schooling, and how well they apply that knowledge in real-world contexts. Some 69 percent of the U.S. students sampled for PISA are tenth-graders. PISA is coordinated by the Organization of Economic Cooperation and Development (OECD), an intergovernmental organization made up of 34 mostly industrialized member countries such as the United States, Japan, Germany, Korea, and the United Kingdom. Some non-OECD member countries, such as Brazil, as well as non-national education systems like Shanghai and Dubai, also participated in the administration of PISA 2009. Other key findings from PISA 2009 include the following:

- In mathematics literacy in 2009, the U.S. average score (487) was lower than the OECD average score (496). Among the 33 other OECD countries, 17 had higher average scores than the United States, 5 had lower average scores, and 11 had average scores not measurably different from the U.S. average.
- A lower percentage of U.S. students scored at or above higher-order proficiency benchmarks in mathematics literacy than the OECD average. Math scores improved from 2006 but were not measurably different from scores on the 2003 assessment.
- In science literacy in 2009, the U.S. average score (502) was not measurably different from the OECD average (501). Among the 33 other OECD countries, 12 had higher average scores than the United States, 9 had lower average scores, and 12 had average scores that were not measurably different.
- For science, the U.S. average score in 2009 was higher than the U.S. average score in 2006, the only time point to which PISA 2009 performance can be compared in science literacy. The gain means that the U.S. science performance is no longer below the OECD average.

NCES's PISA 2009 report provides international comparisons of average performance in reading literacy and three reading literacy subscales and in mathematics literacy and science literacy; average scores by gender for the United States and other countries, and by student race/ethnicity and school socioeconomic contexts within the United States; the percentages of students reaching PISA proficiency levels, for the United States and the OECD countries on average; and trends in U.S. performance over time. Supplemental tables on the NCES website include additional data from PISA 2009, including the percentages of students in all PISA countries reaching the PISA proficiency levels and information on trends in performance around the world in reading, mathematics, and science. The International Data Explorer also now includes PISA 2009 data for the 65 participating countries and education systems and PISA 2000 reading literacy data.

The 56-page report, "Highlights From PISA 2009: Performance of U. S. 15-Year-Old Students in Reading, Mathematics, and Science Literacy in an International Context" is available online at <http://nces.ed.gov/pubs2011/2011004.pdf>.

Blackboard Announces Support for Common Core State Standards

Blackboard Inc. has announced support for the Common Core State Standards, which are now directly accessible for the K-12 community. The integration makes it easy for teachers and administrators to search the standards database from the course environment to ensure that courses and content are aligned to the new standards. To date, 39 U.S. states and territories and the District of Columbia have announced that they will adopt the Common Core State Standards, which define the knowledge and skills students should have in English and math during their K-12 careers in order to be successful in college and the workforce. Blackboard Learn, Release 9.1 already offers alignment with existing academic standards for all 50 states and integrated lesson planning. These new capabilities help teachers align their instruction to standards based curricular requirements and generate reports on consistency. Release 9.1 also includes automated standards mapping which can save districts and teachers countless hours of manual updates when standards

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change. This capability can also help schools and districts make the transition to Common Core standards much faster.

"The Common Core standards are a key component of education reform efforts, and expanding our standards database to include them is an important step in aligning our course platform to the needs of schools and districts," said John Canuel, Vice President K-12 Education Strategy. "This is a key part of our overall commitment to standards based teaching and learning, and leveraging technology to better support teachers and students." The Common Core standards were developed in collaboration with teachers, school administrators, and experts as part of the Common Core State Standards Initiative, a state led effort coordinated by the National Governors Association Center for Best Practices and the Council of Chief State School Officers. For more information about the Common Core State Standards Initiative, visit <www.corestandards.org>.

(*Editor's Note*: The preceding two items were excerpted from the Triangle Coalition Electronic Bulletin for 16 December 2010, reprinted with permission.)

Congress Passes the America COMPETES Reauthorization Act

In an unexpected move at the tail end of the "lame duck" session, Congress passed the America COMPETES Reauthorization Act of 2010 (H.R. 5116) on Tuesday. The bill is now on its way to the President's desk for signature. The COMPETES Act is a game-changing piece of legislation for science, technology, engineering, and mathematics, or STEM, education and makes significant investments in innovation and basic research. The bill includes the STEM Education Coordination Act, which will provide overall coordination of federal programs and activities in support of STEM education. It also reauthorizes a number of other federal STEM education programs including those at the National Science Foundation, National Institute of Standards and Technology, and the Department of Energy. COMPETES is based on recommendations in the National Academies' 2005 *Rising Above the Gathering Storm* report, which recommended investments to support basic research, improve STEM education, and foster innovation.

(*Editor's Note*: The preceding was excerpted from the Triangle Coalition Electronic Bulletin for 23 December 2010, reprinted with permission.)

Refueling the U.S. Innovation Economy: Fresh Approaches to STEM Education

Is the United States getting it wrong when it comes to educating tomorrow's innovators in critical fields? We have known for years that the only way to compete globally in information technology, engineering, nanotechnology, robotics, and other fields is to give our students the best educational opportunities possible. But do we have a successful formula when it comes to science, technology, engineering, and math (STEM) education? A new report released by the Information Technology and Innovation Foundation intends to challenge our approach to STEM education and argues that reforms are urgently needed to better match the talents of students, the needs of employers, and our goals as a nation.

According to the report, *Refueling the U.S. Innovation Economy: Fresh Approaches to STEM Education*, the best and easiest way to produce more and better STEM graduates is to create new institutions that can provide high-quality, best-in-class STEM education. The report recommends that we should fund the U.S. Department of Education to create 400 new specialty STEM high schools. It further recommends that we establish a STEM talent recruiting system by ensuring that the hundreds of outreach coordinators managing the hundreds of federal agency high school outreach programs sites actively work to recruit students with an interest in STEM to the right opportunities for STEM education. Other recommendations:

- Shift accountability measures for high schools from a content-based to skills-based paradigm.
- Reduce course requirements to provide students the opportunity to pursue depth in their K–12 studies, including STEM.
- To help reduce the university freshman STEM student dropout/switchout rate, the President should issue an executive order requesting that at least 30 percent of federal agency-funded undergraduate research experiences be moved to the freshman year and the following summer.

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From Earth to *Eaarth*

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everything else." (p. 208) He concludes his book by explaining how he used the Internet to organize 1400 local rallies against climate change and later to establish his "350.org" to emphasize the critical limit of 350 ppm carbon dioxide to preserve planet Earth.

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The report is available online at <http://www.itif.org/files/2010-refueling-innovation-economy.pdf>.

(*Editor's Note*: See separate story on *Refueling the U.S. Innovation Economy* on page 3 of this issue.)

Exploring NSDL Science Literacy Maps

The National Science Digital Library's (NSDL) Science Literacy Maps have become a popular a tool for teachers to find resources relating to specific science and math concepts in the various collections of the NSDL. The maps help educators understand how K-12 students make progress in their science learning. They also illustrate connections between concepts as well as how concepts build upon one another across grade levels. Digitized versions of the maps were published in Project 2061's *Atlas of Science*. Now, with a new $510,000 grant from the National Science Foundation, Project 2061 will conduct workshops at science education conferences to help teachers use the NSDL Science Literacy Maps more effectively. A set of just-in-time online learning tools will also be developed and embedded in the maps themselves and made accessible through the NSDL Pathways, which serve as the major portals to collections of NSDL resources for K-12 science educators.

Ultimately, the goal of this new effort is to help educators gain a better understanding of the K-12 conceptual and cognitive framework that is presented in the NSDL Science Literacy Maps. These new tools will also help them make better selections and use of the digital resources that are linked to the maps. Project 2061 was founded by the American Association for the Advancement of Science (AAAS) in 1985 to help all Americans become literate in science, mathematics, and technology. For more information about Project 2061's NSDL projects, visit <www.nsdl.org>. To access the Science Literacy Maps, visit <http://strandmaps.nsdl.org>.

(*Editor's Note*: The preceding two items were excerpted from the Triangle Coalition Electronic Bulletin for 6 January 2011, reprinted with permission.)

Momentum Building for Common Core State Standards, Though Full Implementation is Years Away, CEP Survey Finds

States that have signed onto common core state standards in English language arts and math are moving forward with little resistance, though full implementation is several years away for most of them, a new report from the Center on Education Policy (CEP) finds. Most states plan major changes to assessments, curriculum materials, professional development, and teacher evaluation as part of the new standards. Many of these changes, however, are years away. For example, 23 of the 31 states that plan to require school districts to implement the common core standards do not expect to fully institute the requirements until 2013 or later. The CEP report, "States' Progress and Challenges in Implementing Common Core Standards," is based on a confidential survey of state deputy education secretaries. Forty-two states and the District of Columbia responded to the survey between October and November 2010. The goal of the survey was to learn more about state progress toward adopting and implementing the voluntary K-12 common core state learning standards. "States are making progress and see strong support for common core standards, but this is going to take a long time and a sustained effort to see through," said Jack Jennings, CEP's president and CEO. "It's also noteworthy that states vary on approaches to higher education policy and on how much they will require districts to do to support the new standards."

At the time of the survey, 32 states had adopted the standards; four had provisionally adopted the standards, which means that further action is necessary, such as legislative approval; one state decided not to adopt them; and five of the six undecided expected to reach a decision this year while the other was unsure when a decision would be reached. Officials in 36 states said that the rigor of the common core state standards and whether they would serve as a foundation for statewide education improvement were very important or important considerations in their decision to adopt the standards. By contrast, 30 states said they decided, in part, to adopt core standards because they felt it would improve their chances of winning federal Race to the Top funding. (States could cite multiple reasons for adopting the standards.) "The federal incentive of Race to the Top funding clearly played a role in states' decisions to adopt common core state standards," Jennings said. "But, the improvement of education was a more important factor for the states." Many states said it will take until 2013 or later to fully implement the more complex challenges associated with the common core standards. Most states expect to make changes in professional development by 2012 or sooner, but it will take until 2013 or later to fully implement major changes in assessment, curriculum, and teacher evaluation and certification. Of the 27 states that plan to change student assessments by 2013 or later, six gave 2015 as the timeline. "Given the time it's going to take to fully implement the standards and the policy changes

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necessary to support them, it's going to be important that states continue to make progress on other immediate but related efforts to improve schools," Jennings said. The full report is available at <www.cep-dc.org>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 13January 2011, reprinted with permission.)

College Students Lack Scientific Literacy, Study Finds

Most college students in the United States do not grasp the scientific basis of the carbon cycle -- an essential skill in understanding the causes and consequences of climate change, according to research published in the January issue of *BioScience*. The study, whose authors include several current and former researchers from Michigan State University, calls for a new way of teaching -- and, ultimately, comprehending -- fundamental scientific principles such as the conservation of matter. "Improving students' understanding of these biological principles could make them better prepared to deal with important environmental issues such as global climate change," said Charles "Andy" Anderson, MSU professor of teacher education and co-investigator on the project. The researchers assessed the fundamental science knowledge of more than 500 students at 13 U.S. colleges in courses ranging from introductory biology to advanced ecology. Most students did not truly understand the processes that transform carbon. They failed to apply principles such as the conservation of matter, which holds that when something changes chemically or physically, the amount of matter at the end of the process needs to equal the amount at the beginning. (Matter doesn't magically appear or disappear.)

Students trying to explain weight loss, for example, could not trace matter once it leaves the body; instead they used informal reasoning based on their personal experiences (such as the fat "melted away" or was "burned off"). In reality, the atoms in fat molecules leave the body (mostly through breathing) and enter the atmosphere as carbon dioxide and water. Most students also incorrectly believe plants obtain their mass from the soil rather than primarily from carbon dioxide in the atmosphere. The researchers say biology textbooks and high-school and college science instructors need to do a better job of teaching the fundamentals -- particularly how matter transforms from gaseous to solid states and vice-versa. The implications are great for a generation of citizens who will grapple with complicated environmental issues such as clean energy and carbon sequestration more than any generation in history, Anderson said.

NCTM Releases Document to Support Educators In Implementing Common Core State Standards for Math

Triangle Coalition member, the National Council of Teachers of Mathematics (NCTM), has released "Making It Happen: A Guide to Interpreting and Implementing Common Core State Standards for Mathematics," which connects the Common Core Standards with the Council's Standards for school mathematics. Building on the Council's 30-year track record of success in the development of standards for school mathematics, "Making It Happen" supports teachers, districts, and states in implementing the Common Core States Standards for Mathematics (CCSSM). "Adoption of the Common Core State Standards for Mathematics has created a new environment for mathematics education and raised many questions for teachers," said NCTM President J. Michael Shaughnessy. "'Making It Happen' gives teachers an important resource to meet the new challenges of the Common Core Standards by connecting them to the definitive Standards work done previously by the National Council of Teachers of Mathematics."

Through an online interactive e-book and a print companion, "Making It Happen" connects CCSSM to NCTM's "Principles and Standards for School Mathematics," "Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics: A Quest for Coherence," "Focus in High School Mathematics: Reasoning and Sense Making," and the Essential Understanding Series. The online appendixes will continue to be updated as NCTM expands its resources for educators. "Making It Happen" has five main sections, including a section on the key characteristics of school mathematics that are common to CCSSM and NCTM, and a section that provides a road map for teachers as they strive to see how NCTM resources relate to CCSSM and can be used in the classroom to address the new standards. For more information on "Making It Happen," visit <http://www.nctm.org/mih>.

(*Editor's Note*: The preceding two items were excerpted from the Triangle Coalition Electronic Bulletin for 20 January 2011, reprinted with permission.)

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NAEP Releases "Nation's Report Card" in Science

This week, the National Assessment of Educational Progress (NAEP) released the "Nation's Report Card" in science for students at grades 4, 8, and 12 in 2009. National results for each of the three grades are based on representative samples of public and private school students from all 50 states, the District of Columbia, and the Department of Defense schools. State results are reported separately for fourth- and eighth-grade public school students from 46 states and the Department of Defense schools. Student performance is summarized as average scores and as percentages of students performing at or above three achievement levels: Basic, Proficient, and Advanced. Results for student demographic groups (e.g., race/ethnicity, gender, and type of school location) are included, as well as sample assessment questions with examples of student responses. The NAEP science assessment was updated in 2009 to keep the content current with key developments in science, curriculum standards, assessments, and research. Because of the recent changes to the assessment, the results from 2009 cannot be compared to those from previous assessment years; however, they provide a current snapshot of what the nation's fourth-, eighth-, and twelfth-graders know and can do in science that will serve as the basis for comparisons on future science assessments. Highlights of the national results show the following:

- Thirty four percent of fourth-graders, 30 percent of eighth-graders, and 21 percent of twelfth-graders performed at or above the Proficient level, demonstrating competency over challenging subject matter.
- Seventy-two percent of fourth-graders, 63 percent of eighth-graders, and 60 percent of twelfth-graders performed at or above the Basic level in science in 2009, demonstrating partial mastery of the knowledge and skills fundamental for proficient work in the subject.
- Twelfth-graders who reported taking biology, chemistry, and physics scored higher than students taking less advanced science coursework.
- Of the 47 states/jurisdictions that participated at the state level, scores for fourth-grade public school students in 24 states were higher than the score for the nation, and scores in 10 states were lower.
- At eighth-grade, scores for students in 25 states were higher than the score for the nation, and scores for 15 states were lower. In addition, results varied for students of different racial/ethnic groups.
- At grades 4 and 8, White students had higher average scores than other racial/ethnic groups, and Asian/Pacific Islander students scored higher than Black, Hispanic, and American Indian/Alaska Native students. At grade 12, there was no significant difference in scores for White and Asian/Pacific Islander students, and both groups scored higher on average than other racial/ethnic groups.
- Students' performance on the science assessment differed based on the location of the schools they attended. At grades 4 and 8, students attending schools in city locations scored lower on average than students in schools in other locations. At grade 12, the average score for students in city schools was lower than the score for students attending suburban schools, but was not significantly different from the scores for students in town and rural locations.
- Male students scored higher on average than female students at all three grades.

The "Nation's Report Card" is available online at <http://nces.ed.gov/nationsreportcard/pdf/main20009/2011451pdf>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 27 January 2011, reprinted with permission.)

Are College Students Learning Enough Science?

Nearly all American undergraduates take at least one science-related course in college. For many, this coursework marks their last engagement with formal science education. Yet the pace of scientific and technological change means that all adults must be prepared to learn and evaluate new science information after they leave schooling. College graduates, no matter their career, should be proficient in this regard. "In the decades ahead, the number and nature of new scientific issues reaching the public-policy agenda will not be limited to subjects that might have been studied in school but will reflect the dynamic of modern science and technology," writes Jon D. Miller, a contributor to the American Academy of Arts and Sciences's latest publication, *Science and the Educated American: A Core Component of Liberal Education*. The publication explores whether American colleges and universities are providing students with the

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foundation necessary for lifelong scientific learning and targets university administrators and faculty members who are interested in assessing and improving their institutions' curricula. In particular, detailed descriptions of five university science courses highlight innovative methods for conveying complex science information to non-science majors. Several common themes emerge in the volume:

- Without a basic level of scientific literacy, the public cannot rely on even the best science journalism and communications to equip them with the ability to make informed decisions about science issues.
- Science courses belong in the liberal arts curriculum for the benefit of both science and non-science majors.
- Teaching science should convey the wonders and rewards of science but also the limits of science and the dangers of misapplying it.
- Science and the humanities have much more in common than is generally appreciated.

Founded in 1780, the American Academy of Arts and Sciences is an independent policy research center that conducts multidisciplinary studies of complex and emerging problems. Current Academy research focuses on science and technology policy, global security, social policy, the humanities and culture, and education. With headquarters in Cambridge, MA, the Academy's work is advanced by its 4,600 elected members, who are leaders in the academic disciplines, the arts, business, and public affairs from around the world. *Science and the Educated American: A Core Component of Liberal Education* is available online at <http://www.amacad.org/publications/scienceSLAC/aspx>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 10 February 2011, reprinted with permission. *Science and the Educated American: A Core Component of Liberal Education* is reviewed in this issue.)

Ohio Northern University to Launch Undergraduate Degree in Engineering Education

The T.J. Smull College of Engineering at Ohio Northern University has announced that it will offer a Bachelor of Science degree in Engineering Education beginning in the fall of 2011. The degree program will be the first of its kind in Ohio and one of the first in the nation. The program directly addresses the need to develop a new generation of high school students who can contribute to solving our nation's challenges through engineering and innovation. The four-year engineering degree will prepare graduates to become licensed secondary math teachers but with a more specialized perspective than teachers who have a traditional education diploma. "Our nation is pushing for an increased focus on STEM (science, technology, engineering, and math) education in K-12 environments," said Eric Baumgartner, dean of the T.J. Smull College of Engineering. "This degree will enable us to introduce teachers into school systems who have an inherent appreciation of engineering and the ability to integrate math and science along with engineering analysis and design into the classroom."

Teachers with this degree will be the front-line advocates for engineering careers, which, according to research, have not been adequately communicated to high school students. Ohio Northern's program will help maintain America's place as a global leader in science and technology by graduating educators who will inspire young people to pursue higher education and careers in engineering. "We feel that this program builds on the strengths of Ohio Northern as a comprehensive university with excellent programs in engineering and education," said Ken Reid, Director of Freshman Engineering. The program combines a general engineering degree with the required education and math courses to earn a teaching certification, but it also offers opportunities beyond the high school classroom. Graduates can pursue job opportunities in corporate sales, training, or even careers in science and technology museums. Graduates will also be able to seek out traditional engineering careers or go on to graduate school. The reception by high schools has been very positive. Baumgartner has had informal discussions with superintendents across Ohio and all have been incredibly excited about the long-term effect the degree could have on their STEM programs. More details are available online at <http://www.onu.edu/node/33193>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 24 March 2011, reprinted with permission.)

Results of the 2009 NAEP High School Transcript Study Released

The National Assessment of Educational Progress (NAEP) has released "The Nations Report Card: Amer-

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ica's High School Graduates," which includes the latest data and trends on the coursework, academic credits, and grades of U.S. high school graduates and the connection between their level of studies and achievement on NAEP. A rich source of trend information, the results of this study can be compared to earlier findings dating back to 1990. Results highlight the differences among NAEP math and science scores of graduates based on race/ethnicity, gender, and other variables. The results include information about the types of courses graduates took during high school, how many credits they earned, and the grades they received; curriculum level definitions based on earned course credits; the relationships between high school records and performance on NAEP mathematics and science assessments; comparisons to the results of earlier transcript studies, and differences among graduates by race/ethnicity, gender, and other variables. Among the findings:

- In 2009, graduates earned over three credits more than their 1990 counterparts, or about 400 additional hours of instruction during their high school careers.
- In 2005, approximately one in five graduates took algebra I before high school; by 2009, it was about one in four graduates.
- Seventy-six percent of graduates took algebra II in 2009 compared to 53 percent in 1990.
- Seventeen percent of graduates took calculus in 2009 compared to 7 percent in 1990.
- The percentage of graduates who earned credits in the engineering/science technologies and health science/technology courses was larger in 2009 than in 1990 but has not significantly changed since 2000.

The Nation's Report Card is a nationally representative, continuing evaluation of the condition of education in the United States and has served as a national yardstick of student achievement since 1969. Through the National Assessment of Educational Progress (NAEP), The Nation's Report Card informs the public about what students know and can do in various subject areas, and compares achievement data between states and various student demographic groups. The report on “America’s High School Graduates” is available online at <http://nces.ed.gov/nationsreportcard/pdf/studies/2011/2011462/pdf>.

New AAAS Testing Website for Students

The American Association for the Advancement of Science (AAAS) has launched a new website with more than 600 multiple-choice test questions to help educators assess more precisely what students know about key ideas in science and -- just as importantly -- the incorrect ideas they have. Project 2061, founded in 1985 by AAAS to improve science education, developed the assessment items and collected data on them under a grant from the National Science Foundation. The new website presents detailed information on how a national sample of middle and high school students answered each question, along with an analysis of both their correct and incorrect responses to assess whether students truly understand the science concepts they are being taught. The site, which does require registration, also features information on hundreds of misconceptions students have about everything from the size of atoms to whether all organisms have DNA.

Knowing these misconceptions and how pervasive they are – which is not typically part of the analysis of test results from state testing or from leading national and international testing organizations – can help teachers improve instruction and better design their own test questions. In addition to the test questions themselves, the website includes data on student performance by gender, grade level, and whether or not English is the student's primary language. Each question typically was answered by at least 2000 students in field tests involving school districts across the nation. In 2010, for example, more than 90,000 students in 814 schools participated in the field tests. Project 2061 researchers also conducted on-site interviews with students to gauge the effectiveness of the questions. The URL for the AAAS website is <http://assessment.aaas.org>.

(*Editor’s Note*: The preceding two items were excerpted from the Triangle Coalition Electronic Bulletin for 15 April 2011, reprinted with permission.)

CEOs to Governors: Set Higher Bar for Students in Math and Science

A group of prominent chief executives have sent letters to the nation's governors, calling for higher proficiency standards in science and mathematics so that American students will be better prepared to compete globally. The letters were accompanied by new state-specific "Vital Signs" reports assessing the condition of science, technology, engineering, and mathematics (STEM) learning in each state. The CEOs, members of the national non-

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profit organization Change the Equation (CTEq), alerted governors to the reports' finding that most states have not set the bar high enough when measuring student proficiency in STEM subjects. For instance, while many states report that most students are meeting state standards, results from the National Assessment of Educational Progress (NAEP) show only 38 percent of 4th graders and a third of 8th graders are proficient or advanced in math. The CEOs added that states must strengthen instructional supports to ensure students clear a higher bar. "Students in every state deserve the opportunity of a STEM education on par with the best in the world. America's standing as the most innovative and prosperous nation on earth depends on our ability to boost student performance. As business leaders, we are pledging to stand with governors who commit to high achievement standards in math and science," said Craig Barrett, retired CEO/Board Chairman of Intel and Change the Equation Board Chair. The national and state "Vital Signs" reports, show states still have a long way to go. Among the report findings:

- Most states set a low bar. Across all 50 states and the District of Columbia, the average difference between state test results and NAEP was 37 percentage points. A handful of states break the pattern by setting higher proficiency standards.

- Achievement gaps between different groups of students remain large and widespread. In math, gaps separating white students from black and Hispanic peers narrowed substantially between 1973 and 1990 but have barely budged since then.

- Only 10 percent of the class of 2010 took an Advanced Placement test in math, and just 10 percent took an AP test in science. Students who take and pass an AP test are significantly more likely to graduate from college than academically similar students who do not take an AP test.

- Elementary and middle school teachers need stronger grounding in math content. Most states set passing scores on content licensure tests for elementary teachers well below the average for all test takers. Only 57 percent of the nation's 8th graders have teachers with an undergraduate major or minor in math.

- Fifty-four percent of the nation's 4th graders and 47 percent of its 8th graders report that they "never or hardly ever" write reports about science projects. Thirty-nine percent of 8th graders report that they "never or hardly ever" design a science experiment.

The 51 reports were generated by compiling the most recent public data on the condition of STEM learning in each state. Research has already begun for a more in-depth set of Vital Signs reports which will be the most complete examination of STEM learning in each state ever assembled. Supported by the Bill & Melinda Gates Foundation, the new reports will give key information on where each state is making gains, where it has work to do and what it can do to prepare many more of its students for life and work in the coming decades. The national and state-by-state reports are at <www.changetheequation.org/vitalsigns>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 5 May 2011, reprinted with permission.)

Careers in Healthcare and Science? "Not interested," say Half of U.S. Teens

Solid grounding in science is widely considered to be crucial for the next generation of American leaders. From biochemists and pharmacists to physician assistants and physical therapists, the future of the United States job market lies in the fields of healthcare and science. Yet, for the second consecutive year, an online survey conducted by Harris Interactive for University of the Sciences shows that half (49 percent) of all high school-aged students are not interested in pursuing these careers. The 49 percent of 9th-12th grade students who say they are definitely or probably not considering a career in science or healthcare represents an 8.9 percent increase over last year's survey. The lack of interest among younger teens (aged 13-15) grew and stands near 60 percent. Students not considering a career in healthcare and science cite numerous reasons for their lack of interest in these fields:

- 24 percent feel they don't know enough about careers in these fields
- 18 percent feel they're not good enough at science
- 12 percent are not prepared for a career in healthcare/science

Triangle Coalition member, the Sloan Career Cornerstone Center, provides vast and free online resources to help students learn more about science, technology, engineering, mathematics, and healthcare careers. Of high school

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students considering pursuing a career in healthcare and the sciences, only 11 percent state influence from a teacher, and a mere 4 percent say guidance from a school counselor are reasons for their interest. The Cornerstone resources are designed to help students, counselors, and teachers quickly find valuable information about over 185 fields including salary and employment data, career preparation guidelines, tips for exploring careers while in high school, and more. Recent additions to the site include resources about online education options, and state focused portals developed with funding from Triangle Coalition member, Texas Instruments. Find out more at <www.careercornerstone.org>.

Summer Learning Programs Can Stem Students' Cumulative Learning Loss

The loss of knowledge and educational skills during the summer months is cumulative over the course of a student's career and further widens the achievement gap between low- and upper-income students, according to a recent RAND Corporation study. The study, "Making Summer Count: How Summer Programs Can Boost Children's Learning," confirms that students who attend summer programs can disrupt the educational loss and do better in school than peers who do not attend the same programs. Using extensive analysis of existing literature combined with field research, the study examines student summer learning loss and gain, the characteristics of effective summer learning programs, and the costs associated with such programs. It also gives specific recommendations on how school districts can overcome barriers to establishing successful programs.

Researchers find that not all summer learning programs provide equal educational benefits to students. Moreover, many programs suffer from low attendance. Researchers find that students experience the most benefits when the summer programs include individualized instruction, parental involvement, and small class sizes. Despite the clear benefits from these programs, according to the study, many school districts question the cost-effectiveness of summer learning programs and a significant number have discontinued them as a result of budget cuts. While a day of summer instruction costs less than a day of instruction during the school year, summer learning programs are an additional cost. The researchers found that cost is the main barrier to implementing and sustaining summer programs. Researchers make several recommendations for school districts and community leaders to plan and develop summer learning programs, including:

- Invest in highly qualified staff and early planning.
- Apply "best practices" to summer learning programs, such as providing smaller class sizes, getting parents involved, giving individual instruction and promoting maximum attendance.
- Give strong consideration to partnerships, which enable the creation and sustainment of high-quality voluntary summer learning programs.
- Think creatively about funding sources, such as hiring AmeriCorps members and hiring teachers who need administrative hours as summer-site coordinators.

Copies of "Making Summer Count" can be obtained online at <http://www.rand.org/content/dam/rand/pubs/monographs/2011/RAND_MG1120.pdf>.

(*Editor's Note*: The preceding two items were excerpted from the Triangle Coalition Electronic Bulletin for 23 June 2011, reprinted with permission.)

Coal-generated electricity: less CO_2 than an ICE and more efficient than hydrogen

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tricity source to automobile motion of 86%. On the other hand, if the initial electrical energy is used to generate hydrogen from electrolysis, it does so with only 70% efficiency, and the hydrogen compressor passes the hydrogen with only 90% efficiency to a fuel cell, which converts only 40% of its energy to motion of the car. This results in an overall efficiency of energy from electricity source to automobile motion of 25%. This is still almost twice as great as the internal combustion engine's overall conversion efficiency of 14%.

Micromidas: Waste Solids to PHA

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Anticipating Smith's enthusiasm about his work in introducing him, Honey observed that if science were presented with the passion of what it can do for society, all students would want to do it.

Science highlights "Scaling Up Alternative Energy"

"Wind turbines dot ridges, distillers turn farmers' corn into ethanol by the billions of liters, and solar panels sprout on roofs. The energy revolution that will bring us clean, secure energy is under way, sort of." Thus Richard A. Kerr begins *Science*'s most recent special section on energy, in its issue of 13 August 2010. It comes only three years after *Science*'s previous special section on the same topic, on 9 February 2007, reported in our Fall 2009 issue, thus returning the frequency with which they appear to that of the energy-crisis-laden 1970s, which saw two bouts of long gasoline lines – in 1973 and 1979 – and two special energy issues of *Science*, in 1974 and 1978.

The emphasis of the 2007 special section on energy was sustainability. In 2010 it is "Scaling Up Alternative Energy," and in each case the emphasis is the need to move to an energy future that does not depend on fossil fuels. But, as Adrian Cho's charts titled "Energy's Tricky Tradeoffs" in the special section of 2010 testify, we still have 41 years of oil reserves at today's rate of usage, and this is why Kerr can say only that the "energy revolution" is only "sort of" under way. (Never mind that when world oil production peaks, half the world's oil will still be underground and that demand will escalate for that remaining supply to a rate that production will not be able to meet.)

In his story, "Do We Have Enough Energy for the Next Transition?" Kerr writes that when wood came to be in short supply in Pennsylvania, coal replaced it; when whale oil was getting harder to come by, kerosene from newly-discovered oil became the new fuel for lamps. In both cases, he points out, the switch was to a more convenient and useful fuel. But in contrast with fossil fuels, the renewable scheduled to replace them are less dense, more intermittent, and therefore in need of storage systems. With world oil production expected to peak in 2030 and gas able to meet demand through 2050, there is no economic motivation to switch from fossil fuels to renewables, were it not for concern about climate change and the corresponding fact that renewables don't emit carbon dioxide. Meanwhile, he observes, solar energy, which is the only renewable source that could meet all the world's needs, limps along to provide less than 0.2% of the world's energy.

The second news story, "Sending African Sunlight to Europe, Special Delivery," by Daniel Clery, describes the efforts of Desertec to carry out one of the ideas expressed by David MacKay in *Sustainable Energy – without the hot air*, as reported in our Fall 2009 issue: the installation of concentrating solar power plants in North Africa and the Middle East and transmitting their output to Europe via high-voltage direct current. Clery reports that a pilot project, in Morocco, will generate two gigawatts (the equivalent of two electric power plants) at a cost of $9 billion by 2020. The goal is to transmit 500 gigawatts to meet 15% of Europe's energy needs by 2050, at a cost of €400 billion. (This and other aspects of concentrating solar energy are discussed by Martin Roeb and Hans Müller-Steinhagen in a separate Perspective in the same issue of *Science*.)

In the other two news stories in this special section, Eli Kintisch gives a litany of objections to siting wind turbines and what has been done to address them, and Robert F. Service provides an update on the status of producing ethanol from cellulosic sources. Service writes that, in response to Congressional legislation in 2005, the U.S. has already built capacity to produce 15 billion gallons of ethanol from corn per year, an amount which Congress has now set as a cap in 2015, lest even more ethanol production from corn cause more unfair competition for agricultural land (because it raises the cost of food). This turns out to be more than 10% of the 140 billion gallons of automotive fuel the U.S. uses per year, used in a blend of 10% ethanol and 90% gasoline.

It is less efficient, Service continues, for American farmers to make ethanol from corn than for Brazilian farmers to make it from sugar cane, because American farmers must break down the starch in corn kernels in order to have glucose to ferment. This is even more difficult if one uses a cellulosic feedstock, and the current "state of the art" allows only 40% of the energy in cellulosic biomass to be extracted as ethanol, leading to a product twice as expensive as ethanol from corn. (This is consistent with the prices for ethanol from sugar cane, corn, and cellulosic feedstock cited by José Goldemberg in the 2007 special energy section.)

Meanwhile, the U.S. has the capacity to generate all the ethanol fuel from corn that it can use in its present fuel structure. Extracting energy from cellulosic biomass more cost-effectively will not be economically attractive without a greater demand for ethanol fuel, such as would occur if automobile engines were re-engineered to run on "E85," a mixture of 85% ethanol and 15% gasoline.

Just as the dominant topic of the 2007 special energy section was biomass, biomass dominates the 2010 special energy section as well, in spite of Service's less-than-glowing report on progress in producing ethanol from

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Alternative Energy

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cellulosic sources. In fact, all three "Perspectives" in this special section concern biomass. The first, written by a quintet headed by Chris Somerville, assumes the existence of technology to convert most of the polysaccharides of biomass crops to liquid fuels and that the energy to do this will come from burning non-polysaccharide components of the biomass, then proceeds to determine how many GLE (gigaliters of ethanol) can be produced from each biomass source.

One example considered by Somerville is sugarcane, which yielded 27 GLE plus 2 gigawatts from the combustion of bagasse from 4.6 megahectares in Brazil in 2009, thus meeting about 40% of Brazil's liquid fuel use. Somerville's group reports that the Brazilian government is limiting sugarcane production to 63.5 megahectares, of which 60 should be available to produce up to 800 GLE if the polysaccharide component of the bagasse can be converted. This would comprise about 14% of the world's 2006 liquid fuel demand of 4900 GL.

But if biomass is not to compete with food for the Earth's arable land, Somerville's group points out that biomass must be grown on marginal land like the 18% of the Earth's surface that is semiarid, to which *Agave* species are well suited. Trees are also likely to play an increased role in biomass production, for the following reasons: 1) Between 90 and 107 megahectares formerly in agriculture are now urbanized or forested; 2) "The continuing trend to electronic media and paper recycling may reduce the demand for pulp woods and thus presents an opportunity to allocate woody biomass for energy"; 3) Diseased trees need to be removed to avoid forest fires.

Somerville's group writes that ". . . the biomass that is harvested annually in the Northern Hemisphere for wood products has an energy content equivalent to approximately 107% of the liquid fuel consumption in the United States." They provide a table listing requirements and yield for five biomass crops and urge that biomass plantings be characterized by diversity and be harvested in a way that retains minerals in the soil – they are needed for plant growth but not for conversion to biofuel. One way to do this is coppice harvesting – cutting plants near ground level, so that minerals stay below ground in root systems.

With Somerville, *et al*., identifying the most likely biomass crops, Tom L. Richard offers a Perspective on "Challenges in Scaling Up Biofuels Infrastructure." He notes that the International Energy Agency estimates that reducing greenhouse gas emissions by 50% by 2050 will require a fourfold increase in bioenergy production, to 150 EJ per year, 20% of the world's primary energy. This will require 15 billion metric tons, assuming a yield of 17 MJ/kg at 60% conversion efficiency. At a density of 70 kg per cubic meter, he notes that this means a volume of more than 200 billion cubic meters (bcm), significantly more than the 6.2 bcm coal or 5.7 bcm oil used in 2008.

Given the greater volume of less dense biomass fuels, Richard points out that biomass conversion facilities will need to be located to minimize transportation costs, on one hand, while also providing the required throughput to maximize the use of the conversion facility, which Richard regards as "the push-pull between economies of scale for conversion facilities and diseconomies of scale for feedstock supply chains." A 30 MW combined heat and power facility, for example, requires 150 metric tons per day, which can be provided by five semi-trailer loads. But a 200 ML refinery requires ten times as much.

The last Perspective is provided by René H. Wijffels and Marie J. Barbosa on a biomass source not heretofore mentioned: algae. Algae are attractive for bioenergy because of their high productivity of lipids without competing for arable land. Wijffels and Barbosa observe that these lipids in the form of triglycerides can be "converted into biodiesel by transesterification with short-chain alcohols" and converted into linear hydrocarbons by "hydrogenation of fatty acids." Yet they note that the limited production of algae (5000 tons/yr) "is devoted to extraction of high value products such as carotenoids and ω-3 fatty acids used for food and feed ingredients," with a market value of €1.25 billion (€250/kg). Comparing this with an annual production of 40 million tons of palm oil, at a price of only €0.50/kg, they assert that "production of microalgae for biofuels needs to take place on a much larger scale at much lower costs." Their target is a thousandfold increase in production at a tenth the cost and note that the productivity of fungi to produce penicillin has improved five thousandfold in the past 50 years. One step that needs to be taken to increase production is to decipher more algal genomes, so that the most efficient strains can be genetically engineered.

Supplying the annual European biodiesel need of 0.4 billion cubic meters of algae leads to some interesting consequences. It would require 1.3 billion tons of carbon dioxide, about a third of the carbon dioxide emitted by the European Union. Because algae are also 40% protein, 300 million tons of protein would also be produced, 40 times the soy protein Europe imported in 2008.

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RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Willard Cates, *et al*., "Family Planning and the Millennium Development Goals," *Science*, **331**, 1603 (24 Sep 10).

Providing access to safe and effective family planning would enhance the achievement of Millennium Development Goals #1-8: 1) economic development ("each dollar spent on family planning can save up to $31 in healthcare, water, education, housing, and other costs"), 2) education, 3) empowerment for women and girls, 4) child health, 5) maternal health, 6) HIV prevention, 7) environmental conservation, and 8) partnerships across diverse ideologies.

2. Julia Whitty, "The Last Taboo," *Mother Jones*, **35**(3), 24-43 (May+Jun 10).

"Overpopulation, combined with overconsumption, is the elephant in the room," Paul Ehrlich is quoted as saying 42 years after he wrote *The Population Bomb*. Both have contributed to "ecological overshoot," which the Global Footprint Network says began in 1983. While the developed world faults the developing world for overpopulation, the developing world faults the developed world for overconsumption. Overpopulation is "the last taboo," because it smacks of racism, eugenics, colonialism, xenophobia, and forced sterilization or family planning, and the population stabilization efforts of the Sierra Club and Zero Population Growth were derailed because of the anti-immigration activism of John Tanton. But whether we control it will determine whether there will be "a lot of us consuming a lot less or far fewer of us consuming more."

The three transitional stages for nations approaching industrialization are, first, high birth and death rates, leading to slow population growth; second, reduced death rates with the same birth rates, due to improved diet and hygiene; and, third, reduced birth rates to match reduced death rates. Achieving the third stage depends on the literacy of women, as can be seen from the data from the Indian provinces of Bihar and Kerala. But while a woman from a developing country will be responsible for many more descendants than a woman from a developed country, the greater carbon footprint of descendants in a developed country will cause the carbon legacy of the woman in the developed country to be greater. What has improved the lot of women in West Bengal has been microloans from the (private) Bandam program, which also provides health education and rudimentary medical services (the microloan is more successful if the borrower is healthy).

"The paradox embedded in our future is that the fastest way to slow our population growth is to reduce poverty, yet the fastest way to run out of resources is to increase wealth. The trial ahead is to strike the delicate compromise: between fewer people and more people with fewer needs . . . all within a new economy geared to sustainability." (p. 43)

3. Frances Kissling, "Close Your Eyes and Think of Rome," *Mother Jones*, **35**(3), 44-45 (May+Jun 10).

Although a 1930 encyclical from Pope Paul XII approved of pleasure in sexual relations linked to procreation, Pope Paul VI's birth control commission voted to lift the ban on contraceptives in 1966, only to have it rescinded two years later after three dissenting bishops on the commission pleaded with the pope. The Catholic ban on marriage for priests didn't begin until the second millennium, at which point family support and distinguishing between church and personal property became problematic.

4. Clive Thompson, "Nothing grows forever. Why do we keep pretending that the economy will?" *Mother Jones*, **35**(3), 48-53, 79 (May+Jun 10).

Canadian economist Peter Victor has set up a computer model of the Canadian economy with static consumption, productivity, and population after 2010, a four-day workweek, higher taxes on the rich, more services for the poor, and a carbon tax. After "a couple of decades, . . . unemployment . . . fell to 4 percent, most people's standards of living actually rose, and greenhouse gas emissions decreased to well below Kyoto levels. The economy reached a 'steady state.'"

Although Adam Smith acknowledged the finiteness of Earth's resources, John Stuart Mill saw growth as necessary only to attain a reasonable standard of living, and John Maynard Keynes predicted a future economic leveling when we would "prefer to devote our further energies to non-economic purposes," growth continues to be relied on politically as "a hedge against deficit spending and

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high unemployment." Moreover, unlike intangibles such as happiness, it can be measured.

Technology staved off the dire predictions of Malthus, and consumption enabled us to climb out of the Great Depression, but Rachel Carson's *Silent Spring* awakened us to the cost of continued "business as usual." This prompted the Club of Rome to ask Dennis Meadows to organize the study which became *The Limits to Growth* (1974), revised and updated 30 years later. Other examples of literature focused on growth include Herman Daly's *Beyond Growth*, Peter Victor's *Managing Growth* (2008), and Tim Jackson's *Prosperity Without Growth* (2009), which cites Victor's work. The no-growth economy envisions people working and earning less, with buying power of the 1960s and thus a reasonable living standard, and more time to be creative.

(*Editor's Note*: Jackson's *Prosperity Without Growth* is described on the front page of our Spring 2010 issue.)

5. Beryl Lieff Benderly, "The Real Science Gap," *Miller-McCune*, **3**(4), 30-39 (Jul-Aug 10).

From serving the nation in World War II to teaching GIs flooding college campuses to responding to the Soviet launch of *Sputnik* during the Cold War, the need for academically-trained scientists enabled science professors fifty years ago to launch their students with recently-earned PhDs onto successful careers. Today recent PhDs face being placed in a holding pattern of post-doctoral fellowships which enable science professors to complete their research grants with low-paid labor which the National Academy of Sciences has called "disguised unemployment."

While the highly-touted *Rising Above the Gathering Storm* (described in our Fall 2005 issue) chastised U.S. science education for "not keeping pace with the nations needs" and became the basis of the America COMPETES (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Act, "*Storm*'s outsized influence drowned out *Bridge*'s [*Bridges to Independence: Fostering the Independence of New Researchers in Biological Research*] message" that "there are not enough tenure-track academic positions for the available pool of . . . researchers."

Nor has the performance of American students related to those in other countries been as unfavorable as has been reported. TIMSS scores are praised for their consistency and improvement. Moreover, "White Americans on average substantially outscored Europeans in math and science and came in second to the Japanese," but there has been "a growing aversion of America's top students – especially the native-born white males who once formed the backbone of the nation's research and technical community – to enter scientific careers."

Benderly attributes this state of affairs to a dysfunctionality that has emerged in the U.S. research establishment, which Susan Gerbi of Brown University fears "will collapse when it runs out of suckers – a stage that appears to be approaching."

6. Elisabeth Best, "Building With Bamboo," *Miller-McCune*, **3**(4), 26-28 (Jul-Aug 10).

According to this article, bamboo was "the first green plant to reappear after the bombing of Hiroshima" and "has twice the compression strength of concrete and half the tensile strength of steel." It can be used as a food source as well as a construction material. Since certain bamboo species grow very well in most developing countries, these species can serve to underpin these nations' economies. That it does not do so more prominently is attributed to two factors: 1) "its reputation as 'the poor man's timber,'" and 2) lack of standards for bamboo products as construction materials.

7. Eric Wagner, "The Value of Dead Bird Watching," *Miller-McCune*, **3**(4), 40-45 (Jul-Aug 10).

This article describes the work of the Coastal Observation And Seabird Survey Team (COASST) and its founder, Julia Parrish. "I wanted to create a thing that could bring citizens and scientists together," Parish is quoted as saying about her more than 500 volunteers.

8. Sam Eifling, "Snakeheads!" *Miller-McCune*, **3**(4), 66-75 (Jul-Aug 10).

As an invasive species able to reproduce and survive with advantages not available to native species, snakeheads loomed as a cancer to fishing in the state of Arkansas. Just as radiation treatment of cancer tolerates destruction of normal cells in order to kill the cancer cells, Arkansas sought to exterminate its snakeheads by poisoning 400 miles of its waterways.

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9. Toni Feder, “Incentive prizes reinvented to solve problems,” *Phys. Today*, **63**(11), 21-23 (Nov 10).

Originally the prerogative of aristocratic patronage, incentive prizes waned with the waning of aristocratic patronage. But “when you put up a prize, there is fixed money and objective, and you leave time as a variable.” When “World War II came along, . . . the Defense Department needed innovation on a schedule. Money didn’t matter.”

In another case, a prize was able to solve a problem that had eluded twenty years of Defense Department research: the development of an autonomous vehicle. Within two years of announcement of a prize after 9/11, “a group of Stanford University graduate students created a robotic car that was ‘leaps and bound beyond what DOD had previously done. And they did it [spending only] $500,000.’”

Although the Obama administration doesn’t see prizes “as a substitute for funding fundamental research,” it “wants prizes to be ‘among the standard tools in every agency’s toolbox,’” and to this end has established the website <http://challenge.gov> to advertise government-sponsored prizes. “Among the advantages of using prizes and challenges is that the sponsor pays only for success,” and “prizes also increase the number and diversity of people who tackle problems.”

10. Jennifer Weeks, “The Water Detective,” *Miller-McCune*, **3**(5), 18-23 (Sep-Oct 10).

MIT hydrologist Charles Harvey has found that arsenic contamination in Bangladeshi water results when organic materials in water from flood control ponds seeps into the ground, where bacteria use iron oxide to metabolize it and release arsenic. The results of this research can reduce arsenic exposure to not only Bangladeshis but also people in other areas with similar climate and geology, “like Cambodia, West Bengal, and potentially Nepal.”

11. Lucas Laursen, “A Memorable Device,” *Science*, **323**, 11422-1423 (13 Mar 09).

A SenseCam worn around the neck to photograph (automatically) scenes visited during daily activities can aid people with memory problems. Studying the pictures taken by their cameras helped people retain their memories better than keeping a diary did.

12. Richard A. Kerr, “How Much Coal Ramains?” *Science*, **323**, 1420-1421 (13 Mar 09).

Between 1987 and 1990 China cut its estimate of recoverable coal reserves by a factor of 6. Skepticism has been voiced about the recoverable reserves in the U.S., as the amount of coal mined globally is falling below previous predictions and some feel that peak coal production will occur in 2020, followed by a 30-year plateau before declining. David Rutledge, an advocate of doing for coal what M. King Hubbert did for oil, also maintains that burning all the world’s oil, gas, and coal will warm the atmosphere by only 3°C rather than the 8 – 10°C of some scenarios. Those opposed to assessing total recoverable coal from a graph of production *vs*. time point out that technology can stretch its recoverability.

13. Daniel deB. Richter, Jr., Dylan H. Jenkins, John T. Karekesh, Josiah Knight, Lew. R. McCreery, Kasimir P. Nemestothy, “Wood Energy in America,” *Science*, **323**, 1432-1433 (13 Mar 09).

Advanced wood combustion (AWC) systems are now providing between 0.1 to 10 MW_t (megawatts thermal) to European cities for heat and electrical energy – more than 1000 in Austria alone. Wood is now used to heat schools attended by 20% of Vermont’s students. AWC could have a bigger impact in the U.S. if the following were done: 1) choose AWC for new construction and renovation, 2) use wood collected from construction sites and storm damage as a fuel rather than as a waste, 3) develop district systems to provide heat. AWC has the potential of generating energy amounts comparable to those provided by hydro or the strategic petroleum reserve.

14. Vaclav Smil, “Global Energy: The Latest Infatuations,” *Am. Sci*., **99**(3), 212-219 (May-Jun 2011).

Even if the world decides not to heed the threat of global climate change due to carbon dioxide emissions from fossil fuel combustion, it will need to take steps to change from this diet of fossil fuels as the finite supplies of them run out. At the same time, as Smil states, “most of humanity needs to consume a great deal more energy in order to experience reasonably healthy lives and to enjoy at least a modicum of prosperity.”

“Driving was to be transformed first by biofuels, then by fuel cells and hydrogen, then by hybrid cars, and now it is the electrics. . . electricity generation was to be decarbonized either by a nuclear renaissance or by ubiquitous wind turbines,” he writes. But with biofuels supplying only 0.5 percent of the world’s energy in 2010 and

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wind energy only 2 percent of electricity, we've got a long way to go. The less dense energy sources, like wind and solar, which are expected to replace fossil fuels, need large amounts to scale up to the equivalent of an electric power plant (a million photovoltaic panels generate only 80 megawatts of peak solar electricity, less than a tenth of a 1000 megawatt power plant); and a new grid is needed to transport wind and solar electricity from where they are generated to where they are needed. Moreover, the percentage of time ("capacity factor") that sources like wind and solar generate electricity is much lower than the capacity factor of today's power plants.

Changing to the less dense, but carbon-free, energy sources of the future will not be easy, Smil continually reminds his readers, especially with increasing energy appetites from the developing world. And "new energy conversions are thus highly unlikely to reduce CO_2 emissions fast enough to prevent the rise of atmospheric concentrations above 450 parts per million." But some relief could come if the United States and Canada reduced their per capita energy consumption, Smil says. There is gap caused by a 2:1 ratio of per capita energy in North America and the European Union and Japan, "and even a multiple adjustment of national per capita rates for differences in climate, typical travel distances and economic structure leaves most of the U.S.-E.U. gap intact."

15. Cameron Reed, "From Treasury Vault to the Manhattan Project," *Am. Sci*., **99**(1), 40-47 (Jan-Feb 2011).

With electromagnetic mass spectroscopy needed to separate sufficient quantities of the fissionable isotope U-235 from the more prevalent U-238 and copper in great demand for shell casings during World War II, the Manhattan Project arranged to borrow more than 14,000 tons of silver from "the West Point Bullion Depository in West Point, New York, a Treasury facility known as 'The Fort Knox of Silver.'" This article charts the journey of that silver through two stops for processing in New Jersey and one in Milwaukee between 1942 and 1944 before it was installed into "calutrons" patterned after Ernest O. Lawrence's cyclotrons in Oak Ridge, TN. While the calutrons continued to separate isotopes until 1998, they did so after they were refitted with copper electromagnets – the silver was returned by 1970; and because scrap recovery was so effective in the processing stages, more was returned than had originally been borrowed.

16. John H. Falk and Lynn D. Dierking, "The 95 Percent Solution," *Am. Sci*., **98**(6), 486-493 (Nov-Dec 2010).

In the TIMSS and PISA program of international standardized tests, Americans in elementary school excel in comparison with their counterparts throughout the world. Moreover, "for more than 20 years, U.S. adults have consistently outperformed their international counterparts on science literacy measures." "Although data show that taking college level science courses dramatically improves public science literacy," Falk and Dierking write, "only about 30 percent of U.S. adults have ever taken even one college-level science course." Given that "consistent science instruction in U.S. schools only begins at the middle-school level," they suggest that what young children and adults do in the 95 percent of their lives outside of school is responsible for their knowledge of science – *i.e.*, visiting science museums and zoos, watching science programs on TV, pursuing science-related hobbies, delving into library resources (especially the Internet) for an in-depth knowledge of a science-related topic of personal interest, all examples of what they call "learning for life" rather than "learning for school." "Insufficient data exist to conclusively demonstrate that free-choice science learning experiences currently contribute more to public understanding of science than in-school experiences," Falk and Dierking write, "but a growing body of evidence points in this direction." If they are right, we would be well advised to increase opportunities for free-choice science learning experiences.

17. Peter Friederici, "The World's Best Bad Idea," *Miller-McCune*, **3**(6), 47-53 (Nov-Dec 2010).

Sequestration of carbon captured from fossil-fueled plant emissions underground has superseded earlier interest in deep sea sequestration, but the NUMBY ("Not Under My Back Yard") syndrome may bring about reconsideration of deep sea burial. There are concerns, though: one is cost (calculated at $40 per ton of carbon captured, requiring between 15 and 40% of a coal-fired plant's energy output); the other is environmental (the 1972 London Convention forbidding dumping of wastes at sea needs to be amended; and, while deep ocean pressure will compress carbon dioxide into a liquid denser than water, the carbon dioxide will eventually find its way to the surface of the ocean and acidify it).

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REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCE

Stephen L. Macknik, Susana Martinez-Conde, with Sandra Blakeslee, *Sleights of Mind: What the Neuroscience of Magic Reveals About our Everyday Deceptions* (Holt, New York, 2010), 291 pp. $26.00. ISBN 978-0-8050-9281-3.

Stephen Macknik is the director of the Laboratory of Behavioral Neurophysiology at the Barrow Neurological Institute in Phoenix, AZ. Susan Martinez-Conde is the director of the Laboratory of Visual Neuroscience at the Barrow Institute. This husband-wife team enlisted the services of Sandra Blakeslee (who similarly assisted Jeff Hawkins in writing *On Intelligence*, reviewed in our Winter/Spring 2009 issue) to produce "the first book ever written on the neuroscience of magic, or, if you will, *neuromagic*. . . ." (p. 2) Their reasons for doing so seem to be twofold: given the ways magicians have exploited neuroscience in the development of their craft, they wanted to learn what magic can teach us about neuroscience; and, in the course of learning this, they sought to develop their own performance skills to be accepted as members of the Academy of Magical Arts at the Magic Castle in Los Angeles.

The basis for the neuroscience of magic is that the human brain is limited in the number of things it can focus on at one given time. And the more intently the brain is focused on the object of attention, the less attentive it is to everything else. As Macknik and Martinez-Conde express it, "When you attend to something, it's as if your mind aims a spotlight onto it. You actually ignore virtually everything else that is happening around your spotlight, giving you a kind of 'tunnel vision.' Magicians exploit this feature of your brain to maximum effect." (p. 60) They "control . . . attention, memory, and causal inference, with a bewildering combination of visual, auditory, tactile, and social manipulations." (p. 59) And while they are controlling our attention in one place, they are wreaking their "magic" somewhere else.

Our expectations are based on the model of the world we have built on the basis of our experience, and we continually incorporate new experience to revise that model. Thus, "perception is not a process of passive absorption but of active construction." (p. 141) We are entertained when our expectations are challenged by a surprise. "Our brains are correlation machines, as the magicians prove to us over and over with the presentation of impossible causal events." (p. 184) "A great magician makes you experience the impossible by disrupting normal cause-and-effect relationships." (p. 242) ". . . the enduring mystery about magic is how the brain constructs – and falls for – illusions." (p. 251)

Macknik and Martinez-Conde feel that "magicians have tapped into the power of cognitive illusions more effectively than scientists have, though less systematically." (p. 252) Doing this requires a lot of effort and the development of considerable skill (Macknik and Martinez-Conde describe the extensive and exhaustive schemes some famous magicians employ to achieve amazing feats of memory.). Although the "readiness to make correlations illustrates the general processes by which people succumb to the belief in the paranormal" (p. 185), the authors definitively state that there is a physical explanation for all magic, adding that "if magicians are artists of attention and awareness, psychics are poseurs of false wizardry." (p. 205)

You can read the physical explanation of most of the magic Macknik and Martinez-Conde describe in their book if you read their sections labeled "spoiler alert," but they point out that they are not unique in publishing the secrets of magic. "You can find complete descriptions and explanations on the Internet of just about every magic trick ever invented," they write (p. 242); they also point out that Reginald Scot wrote *The Discoverie of Witchcraft* in 1584 to end witch hunts by showing that magic is achieved by natural means. The spoiler alerts, warning of a secret to be revealed, are inserted, they write, to adhere to the "ethical guidelines of the magicians' associations to which we belong, which insists that the public must not learn a secret by accident." (p. 243)

Although most of what Macknik and Martinez-Conde have written concern how magicians have exploited neuroscience, they write that because "magic profoundly manipulates the nature of our conscious experiences, it holds the promise of revealing some of the most compelling scientific discoveries imaginable." (p. 255) They continue by noting that "the study of the neural basis of consciousness used to be considered an impossible field of inquiry. Now dozens of labs, including both of ours, investigate the activity of neurons in relation to conscious versus unconscious perception." They also champion Francis Crick's pursuit of the "neurobiological study of consciousness back when it was considered uncouth" and

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cite Crick's "first popular book on the study of consciousness," *The Astonishing Hypothesis*." (p. 255)

- John L. Roeder

Jerrold Meinwald and John G. Hildebrand (eds.), *Science and the Educated Person: A Core Component of Liberal Education* (American Academy of Arts and Sciences, 2010), x + 266 pp. Available online at <http://www.amacad.org/publications/scienceSLAC/aspx>.

This volume grew out of a conference sponsored by the Academy in 2007 at which leaders from 34 institutions gathered "to discuss science curricula for non-science majors." (p. vii) Having developed his own course for nonscience majors at Cornell, "The Language of Chemistry," as a result of interesting fellow faculty from other disciplines in his research on the communication between insects with chemicals, Meinwald organized this conference during a sabbatical leave at the Academy and asked Hildebrand to join him. The result is a volume that "aims to examine some of the reasons why science education for all students is a significant educational objective; to present some views of what we mean by scientific literacy; to describe several imaginative approaches to teaching science for students majoring in any discipline; and to recommend steps that will help faculties and administrators devise undergraduate liberal arts curricula that will equip future generations of graduates to recognize and appreciate the beauty, value, and utility of scientific thought, investigation, and knowledge." (p. 1)

Among those whose views of scientific literacy are no strangers to this *Newsletter* are James Trefil and Robert Hazen. Their contribution, titled "Scientific Literacy: A Modest Proposal," begins by citing John Dewey's rationale for science education (1909):

> Contemporary civilization rests so largely upon applied science that no one can really understand it who does not grasp something of the scientific method. . . . The formation of scientific habits of mind should be the primary aim of the science teacher in the high school. (pp. 57-58)

The motivation to include science in the curriculum expected "that a magic bullet called the 'scientific method' would somehow transform students into logical, reasoning human beings." (p. 58) Though this goal may be worthy, Trefil and Hazen find it to be unrealistic except for the small percentage of students who "will go on to distinguished careers in science and technology fields." (p. 58) For the rest they feel that a more realistic goal is scientific literacy, which they define as "*the matrix of knowledge needed to understand enough about the physical universe to deal with issues in the news and elsewhere.*" (p. 58) – just as literacy about economics and law enables people to read news articles about business and court cases. Scientific literacy encompasses understanding the role of the processes of science and how they enable us to know about the world, plus specific knowledge about core concepts and structures in terms of which we understand nature. Trefil and Hazen acknowledge that this is not the "true" scientific literacy, as described by Morris Shamos, which is more along the level envisioned by Dewey "yet does not recognize (as Dewey implicitly did) that such a goal is appropriate only for the small fraction of students who major in science." (p. 59) (Shamos, for example, wrote that appreciating science required experiencing the role played by mathematical reasoning.)

"A common fallacy in science education is that every student should think like us," Trefil and Hazen write (p. 59), citing the many types of intelligence identified by Howard Gardner. "Accordingly, we need to acknowledge the difference between scientific competence and scientific literacy. . . . no matter how technological the economy becomes, most people will never need to do science for a living. Everyone, however, will need to be scientifically literate to function effectively as a citizen." (p. 60)

Two propositions underlie Trefil and Hazen's "Modest Proposal":

1) "We have to teach the students we have, not the students we wish we had."
2) "If we expect students to know something, we have to tell them what it is."

Regarding the first, they rue that they don't have sufficient time to address writing inadequacy, and inevitable math phobia requires that they focus on science without math. Regarding the second, they note that they cannot just teach the "scientific method" and expect students to be able to derive all that is known in science from it.

Trefil and Hazen's approach to scientific literacy in general, and undergraduate science education in particular, focuses on the content of their "approximately twenty 'great ideas of science'" (p. 62), originally developed in their book *Science Matters*, which was published in its second edition in 2009. (The first edition was reviewed in

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our Fall 1991 issue.) In addition to this "great ideas of science" curriculum, their preferred way to meet the science education needs of nonscience majors includes courses on "broad topics such as energy, evolution, the environment, or forensics; explorations of scientific current events and public policy; and courses that explore science from historical and/or philosophical perspectives." (p. 69)

A scientifically literate person, as defined by Trefil and Hazen, would have sufficient understanding to read the "Science Times" section of *The New York Times*; but, according to Jon Miller's chapter on "The Conceptualization and Measurement of Civic Scientific Literacy for the Twenty-First Century," only 28% of American adults have sufficient understanding of science to do this. While most of this understanding must be acquired *after* formal schooling, Miller writes that "formal education, when done well, can provide a necessary conceptual foundation for a lifetime of scientific learning. . . ." (p. 241) While international testing shows that American secondary schools are *not* providing this foundation as well as it should, Miller observes that required college science courses are remedying this deficiency to a large extent.

In the past, scientific literacy has been considered in terms of factual knowledge, but Miller feels that a formulation more appropriate for the twenty-first century may be more appropriately based in what is meant by literacy itself – "the level of understanding of scientific and technological constructs needed to function as citizens in a modern industrial society" (p. 243), along the lines of "Rutherford's original conceptualization of Project 2061." (p. 252) He distinguishes among three types of scientific literacy – consumer, civic, and cultural. But, given the scientific issues he considers to be of greatest concern – global climate change, use of embryonic stem cells, future energy sources, and a viral pandemic in the U.S.; nuclear power and genetically modified foods – he assigns a primacy to *civic* scientific literacy and feels that "schools and universities have a special responsibility to foster civic scientific literacy in our society." (p. 243) Civic scientific literacy should "provide valuable curricular guidance for high school science courses for all students and college courses for non-science majors." (p. 243) Miller notes that UC-Berkeley has followed this recommendation by changing "the name of its introductory physics course from Physics for Poets to Physics for Future Presidents." (p. 243)

In his survey of scientific literacy, based upon a set of questions originally developed in collaboration with two British researchers in 1988, Miller seeks to measure "the acquisition of basic scientific constructs that are likely to be useful to students and adults over the course of a lifetime in acquiring and making sense of emerging scientific ideas and developments." (p. 243) Although specific aspects of concern in science have changed through the years, survey results can be linked by tabulating the results on questions examining the same topic over a series of years. Two continuing topics are defining the meaning of a scientific study and describing an experiment. In 2008, 34% of American adults were able to do the former, up from 22% in 1988; 61% of American adults in 2008 could do the latter.

From his data Miller has constructed a "summary index of CSL (Civic Scientific Literacy), with scores ranging from roughly zero to one hundred." (p. 247) A score of 70 or better has been assessed as one enabling a person to read *The New York Times* Science Times stories or watch an episode of *NOVA* with understanding, and the percentage of American adults scoring more than 70 increased from 10% in 1988 to 28% in 2008. Of ten selected variables he considers for their effect on civic scientific literacy, he finds only two showing a strong impact – college science courses (with an effect of 0.74 in his evaluation model) and educational attainment (0.69). But Miller is quick to add that "the accelerating pace of scientific development means that most Americans outside the scientific community will learn most of their science after they leave formal schooling." (p. 252)

Miller comments extensively on what he sees as the influence of religious fundamentalism on civic scientific literacy. Of the ten selected variables considered for their effect on civic scientific literacy, religious fundamentalism was found to have a negative effect of -0.20. Miller also observes the influence of religious fundamentalism in a reduced acceptance of the Big Bang (from 34% in 1958 to 30% in 2008) and evolution (from 47% in 1988 to 37% in 2008), and he foresees this influence continuing into the twenty-first century:

> In broad terms, the twentieth century was the century of physics, and the twenty-first century will be the century of biology. The twentieth century was characterized by enormous advances in transportation, communication, and nuclear science—from the radio to the airplane to the transistor. Although these new developments and technologies eventually changed the very character of American society, most of them successfully avoided direct confrontation with traditional beliefs and values, especially religious values. As science continues to expand our understanding

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> of the nature and structure of life and develops the technologies to intervene in those processes, the resulting political disputes will become more personal and more directly confrontational with traditional religious values. (p. 253)

The developer of the "Physics for Future Presidents" course cited by Miller is Richard A. Muller, who wrote his own chapter on "Physics for Future Presidents" for this volume. "Physics is the liberal arts of high technology. Understand physics, and never again be intimidated by technological advances," he writes (p. 117), adding that "We can – we must—achieve the same level with scientific literacy [as for literacy in general], especially for our leaders." (p. 112) Muller explains that he developed "PffP" from his "experience presenting tough scientific issues to top leaders in government and business," which led him to conclude that they "are smarter than most physics professors." (p. 112) This course began with 34 students in spring 2001 and the enrollment increased to more than 500 by the fall of 2006. Muller reports that students take and enjoy this course because it "fills them with information and the ability to use it well." (p. 114)

Muller writes that he teaches by immersion in "physics as a second language," with the intent that his students will use "physics terms in their specialized physics sense when talking to other physics-literate people. . . . When you know how to use specialized language, you can communicate more effectively with other experts." (p. 117) He adds that he wrote his textbook as a novelist would, not as a textbook author. Unlike Trefil and Hazen, Muller places high emphasis on the quality of writing – clear, concise writing, as is needed for briefing a president – in his evaluation of student work. His goal is that PffP will be a commencement for future learning about physics through empowerment.

Muller, whose lectures are available on You Tube, concludes that "Yes, learning is hard. . . . The trick is not to mind that it is hard. As students rediscover the joy of learning, they will learn with much less effort." (p. 121) He also encourages his students to discuss what they learn as an aid to retaining it.

Addressing a wide range of issues related to scientific literacy and offering a rejoinder to some of the other chapters is Chris Impey, whose chapter is titled "Science Education in the Age of Science." "If we are to help students become more than just passive participants in the Age of Science, we must redouble our efforts to help them understand the great intellectual adventure that is reshaping the world," he writes (p. 70). He acknowledges the differences in philosophy underlying the need for scientific literacy – Trefil and Hazen's argument on the basis of general comprehension, Miller's argument for an informed citizenry to provide input to public policy, and Shamos's regarding scientific literacy, as he defined it, to be an unrealistic goal – then goes on to report his own polling about scientific literacy among students at his home institution, the University of Arizona, with questions used by the National Science Foundation to poll the American public for *Science and Engineering Educators*. The overlap between Impey's list of questions and Miller's list of questions suggests that their two sets of questions are the same, but the results Impey reports differ from those of Miller. Impey's results do not agree with Miller's correlation of scientific literacy with educational attainment and college science course. Rather, Impey attributes people's scientific knowledge to their high school education, although he presents data showing improved responses for two questions as the number of college science courses increases. Impey is also concerned about Arizona students' responses to other questions which indicate beliefs in pseudoscience.

After addressing the need for and status of scientific literacy, Impey turns to the contrast between traditional teaching and what has been learned about learning. Impey describes traditional teaching as

> the unspoken pact that can develop in the classroom. The professor agrees to deliver a highly structured presentation, not to ask students to think outside the box, and to evaluate them according to the material in the textbook with objective tests, usually multiple choice. In return, the students agree not to be disruptive, to act as tidy receptacles for information, and to regurgitate that information when it is time for a test. . . . As long as nobody questions the premise, and the grades connect to the content that is being taught, everyone is fairly happy. (p. 91)

His primary resource for what has been learned about learning is *How People Learn*, reviewed in the Winter 2003 issue of this *Newsletter*, and he notes that the currently-advocated "learner-centered techniques challenge faculty to relinquish some authority and control in the classroom."

Finally, Impey addresses where people are getting their scientific literacy – primarily, the Internet, which he calls the second of "only two real revolutions . . . in the delivery of instruction," (p. 100), the other being the overhead projector (in 1969). "In 2010 . . . 10^{19} bits . . . will be added to the digital universe," he writes (p. 79), noting

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that in June 2008 Google indexed its trillionth web page. Among those web pages, the Wikipedia, with four million articles, dwarfs all other information resources. Impey observes that a study commissioned by *Nature* found the Wikipedia as reliable as the *Encyclopedia Brittanica*, though the former's quality of writing is more uneven, and recommends that scientists take responsibility to insure the accuracy of Wikipedia articles. In addition, he notes the more than 500 terabytes of data posted at NOAA's National Climate Data Center and more than 50 terabytes at NASA's High Energy Astrophysics Archive. Furthermore, "the ability to perform robust semantic searches will greatly increase the power of the Internet as a learning tool," and Impey cites the efforts in this direction made by <www.wolframalpha.com> and <www.bing.com>.

Impey also cites the "open-access collection of several thousand peer-reviewed and annotated learning resources" known as MERLOT (Multimedia Educational Resource for Learning and Online Teaching) (p. 101) and new "transformational technologies" which "will soon have tremendous influence on . . . the ways in which we teach" (pp. 102-103):

1) Mobile learning: "small-format computers," which will mean more devices connected wirelessly to the Internet than were connected by wire in 2009.

2) Semantic web: This "will transform knowledge retrieval just as search engines transformed web page retrieval. If a student can get a natural-language query answered in real time . . . retention of specific knowledge will be superfluous, just as the skill of navigation is waning with the spread of devices that take advantage of the Global Positioning System."

3) Ubiquitous computing: when "Internet bandwidth will . . . allow the network to 'become' the computer."

4) Social networks: Facebook has more than 400 million users, a hundred million in the U.S., including nearly 90% of U.S. undergraduates. Although only a few hundred of the more than 100,000 Facebook apps are educational, there is the potential to "create collaborative learning tools and online learning communities."

5) Virtual worlds: "More than 250 universities already have a presence in Second Life." Seventy thousand of Second Life's 15 million users are "in world" at a given time. Among its "virtual planetariums and science centers" are "installations run by NASA and NOAA" and a 16-acre island maintained by Impey, which "has been successfully used in general education classes for non-science majors." Impey adds that "conventional teaching is not well suited to a virtual world, but cooperative learning, model building, and 3-D visualization of science concepts work well."

Meinwald and Hildebrand's recommendation for achieving scientific literacy is a package of four semester courses for college graduation: two of the "Trefil/Hazen persuasion to provide students with basic grounding in the fundamentals of physical and biological scientific knowledge," plus "two additional one-semester courses emphasizing how scientific knowledge has been successfully gained in the past, and how much more remains to be discovered. . . ." (p. 8)

\- John L. Roeder

(*Editor's Note*: Although the views of Morris Shamos on scientific literacy are frequently cited in this book, Shamos is not able to represent himself directly because he is now deceased. Shamos's views on scientific literacy have been extensively covered in earlier issues of this *Newsletter*, beginning in January 1984. Twice he spoke to the Scientific Literacy Seminar at Columbia University (Spring 1990 and Winter 1996 issues), and his interaction with others has also been featured – with Audrey Champagne at NASTS and with Robert Yager and Joe Piel at NSTA (Spring 1990), and with Rodger Bybee at the New York Academy of Sciences (Fall 1996).)

Clearinghouse Update

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as the major portals to collections of NSDL resources for K-12 science educators. Ultimately, the goal of this new effort is to help educators gain a better understanding of the K-12 conceptual and cognitive framework that is presented in the NSDL Science Literacy Maps and to help them make better selections and use of the digital resources that are linked to the maps.

In addition to the new grant, Project 2061 is also funded by the NSDL program to build the capacity of digital library developers to determine how well their resources address K-12 science content standards. For more information about Project 2061's NSDL projects, please contact Principal Investigator Francis Molina, (202) 326-7002.

(*Editor's Note*: The foregoing was taken from the December 2010 online issue of *Project 2061 Connections*.)

RESOURCES

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18. Valerie Brown, "Bacteria Я Us," *Miller-McCune*, **3** (6), 64-73 (Nov-Dec 2010).

"The tree-of-life notion remains a reasonable fit for the eukaryotes," writes author Brown, "but emerging knowledge about bacteria suggests that the microbiosphere is much more like a web." Although bacteria don't reproduce sexually, they can exchange genes with each other, to the point that "the notion of separate bacterial species is somewhat shaky." Bacteria also engage in group behavior, which "has now been demonstrated so widely that many microbiologists view bacteria as multicellular items, much of whose activity . . . . is mediated by a wide variety of chemical communications." Yet for all the blurring between species as the consequence of genetic exchange, "Bacteria can distinguish 'self' from 'other.'"

Another new view of bacteria advanced by this article is that, although "the germ theory of disease and the subsequent development of antibiotics are two of medical science's greatest accomplishments," is that microbes are *not* "enemies in a permanent war." Rather, "Recent research has shown that gut microbes control or influence nutrient supply to the human host, the development of mature intestinal cells and blood vessels, the stimulation and maturation of the immune system, and blood levels of lipids such as cholesterol." This brings author Brown to her title: ". . . in a very real sense, bacteria are us," to the point that some are attributing physiological diseases to "imbalance in the ecology of the microbes inhabiting the human body." Examples supporting this viewpoint are "fecal transplants [which] resulted in almost immediate and long-lasting relief for people suffering from . . . chronic antibiotic-induced diarrhea" and a "study [that] found that the microbiota of obese adults were very different from the bacteria populations of both normal-weight people and obese people who had had gastric bypass surgery."

Brown therefore characterizes bacteria as the "supreme code monkeys that probably perfected the packages of genes and the regulation necessary to produce just about every form of life, trading genetic information among themselves long before there was anything resembling a eukaryotic cell, let alone the masters of the universe that humans believe humans to be." She continues that "the idea that humans are separate from and superior to everything else in the biosphere . . . has taken a terminal blow from the new knowledge about bacteria" and concludes that "if there's any hope of rebalancing the chemistry of a biosphere deranged in two short centuries by humans, it very likely lies in peaceful coexistence with the seemingly brilliant, deceptively simple life-forms comprising the domain Bacteria."

Alternative Energy

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The section on "Scaling Up Alternative Energy" concludes with a Review by Robin W. Grimes and William Nuttall, "Generating the Option of a Two-Stage Nuclear Renaissance." The two stages imagined by Grimes and Nuttall are what can be done now and what can be done after 2030. Decarbonizing the global electricity system requires civil nuclear programs "without risking the proliferation of nuclear weapons technologies" and dealing "with nuclear waste in as safe a manner as possible," they write; ". . . the most immediate challenges are nuclear life extension and how best to renew nuclear generation infrastructure."

While the immediate (present) response is to preserve the present nuclear contribution to electricity generation, the second phase, beyond 2030, is to increase the amount of nuclear-generated electricity in order to "decarbonize" it. This will also come at a time that efforts to decarbonize heating and transportation will make them more reliant on electricity. With Gen [for "generation"] I reactors described as "prototype power reactors and first designs connected to the grid," Gen II as "current operating reactors," and Gen III as "designs about to be deployed" (based on Gen II but with some active responses to faults converted to be passive), the post-2030 phase will come with new reactor systems called "Gen IV." They are expected to provide industrial process heat, and surplus electricity could be used to generate hydrogen fuel or to desalinate water. Grimes and Nuttall write that Gen IV reactors should have 70-year lifetimes and higher burnup of uranium (up to 19%), enabled by increasing the thermal conductivity of the reactor core by adding silicon carbide or magnesium oxide.

Grimes and Nuttall conclude with six suggested sustainable nuclear energy alternatives: 1) continuation of once-through use of uranium but extracting it from phosphates and sea water at higher prices; 2) processing spent fuel to make mixed uranium-plutonium oxide fuel; 3) building critical fast reactors, fissioning all isotopes of uranium and having the potential to "breed" plutonium fuel; 4) "breeding" uranium-233 from thorium-232 (attractive to India, with large thorium deposits; see Resource #2 of our Fall 2010 issue); 5) producing accelerator-driven subcritical reactors, and 6) achieving nuclear fusion, though not expected before 2050 (this could operate in conjunction with fission).

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Rustum Roy: Founder of NASTS

Rustum Roy founded many things during his 64-year career at Penn State University, which began with his earning his PhD there – the Materials Research Laboratory; the International Materials Research Society; and the Science, Technology and Society program there. Most important to readers of this *Newsletter*, he was the founding president of the National Association for Science, Technology, and Society.

Roy also took an interest in this *Newsletter* and frequently contributed to it. We are sad to report that he died at age 86 in State College, PA, on 26 August 2010. His death leaves a large void in the STS community, and his presence will be greatly missed.

Remembering Rusty

by Sara Anderson

I was greatly saddened to read Rustum Roy's obituary. When I was a student, "Rusty," as everyone called him, was a frequent speaker and facilitator of discussions for the University Christian Association, a non-denominational student group. I was intrigued by this witty, lively scientist who was also a religious philosopher.

In 1987, I attended the first Technological Literacy Conference (TLC) and was pleased to again meet Rusty, the conference organizer. The TLC was classic Rustum Roy: an eclectic group of educators from all levels, scientists, and government and business officials. The sessions were mind-opening and inspiring.

Throughout the 1980s and into the '90s the conferences – renamed the Science, Technology, and Society Conferences – were held in Arlington, VA, and the National Association for Science, Technology, and Society was formed, with Rusty as its first president. I wish I could say we were uniformly successful in breaking down disciplinary and institutional boundaries. We were not. But STS programs such as Penn State's continue today, and the wisdom of interdisciplinary and cross-organization work has become much more widely accepted than it ever would have been without Rusty's efforts.

I was always proud of Penn State for giving Rusty the platform from which to make his contributions to STS education, health sciences, and government and business policy. He will be greatly missed.

(*Editor's Note*: This remembrance is reprinted from the May/June 2011 issue of *The Penn Stater*, courtesy of the author, a frequent contributor to this *Newsletter* and a 1963 graduate of Penn State.)