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Brahmia's synthesis of CCSS, NGSS, and AP

When Suzanne White Brahmia, director of the Extended Physics program and the associate director for physics of the Math and Science Learning Center at Rutgers University, spoke on 14 March 2015 to the New Jersey section of the American Association of Physics Teachers (NJAAPT) on "NGSS, CCSS-Math, and the New AP: An Opportunity for Students to Develop Physicists' Ways of Thinking," she synthesized the practices of these three new developments in education into four clusters of practices that embody what she feels is the essence of physicists' ways of thinking: 1) mathematization as a way of reasoning, and 2) experimentation as a way of creating knowledge. Three of those clusters reflect three aspects of "mathematization": 1) Reasoning mathematically with physical quantities: Reasoning abstractly and quantitatively; making sense of problems, using appropriate mathematical tools and persevering; 2) Reasoning with mathematical models: Developing and using mathematical models and explanations, constructing viable arguments, engaging in argumentation from evidence and critiquing the reasoning of others; and 3) Reasoning based on mathematical structure: Looking for and making use of patterns associated with mathematical structure to reason across contexts and scale. The fourth cluster embodies Experimentation as a way of creating knowledge: Formulating a scientific question, designing and carrying out experiments, analyzing and interpreting data while attending to uncertainty in measurement and constructing explanations.

The Common Core State Standards in Mathematics (CCSS-Math) were adopted in New Jersey in 2010. The Next Generation Science Standards (NGSS) were adopted by the New Jersey State Board of Education on 9 July 2014 and are to be implemented in grades 6-12 by the start of the 2016-2017 school year. The Advanced Placement (AP) Physics B course has been replaced by the AP 1and AP 2 courses, with the first AP test to be given May 2015. As presented by Brahmia, these three developments are based on the following practices:

CCSS – Mathematical Practices:

CC1. Make sense of problems and persevere in solving them.
CC2. Reason abstractly and quantitatively.
CC3. Construct viable arguments and critique the reasoning of others.
CC4. Model with mathematics.
CC5. Use appropriate tools strategically.
CC6. Attend to precision.
CC7. Look for and make use of structure.
CC8. Look for an express regularity in repeated reasoning.

NGSS Scientific and Engineering Practices:

NG1. Asking Questions and Defining Problems
NG2. Developing and Using Models
NG3. Planning and Carrying Out Investigations
NG4. Analyzing and Interpreting Data
NG5. Using Mathematics and Computational Thinking
NG6. Constructing Explanations and Designing Solutions
NG7. Engaging in Argument from Evidence
NG8. Obtaining, Evaluating, and Communicating Information

AP Physics Practices:

AP1. Use representations and models
AP2. Use mathematics appropriately
AP3. Engage in scientific questioning to guide investigations
AP4. Plan and implement data collection strategies
AP5. Perform data analysis and evaluation of evidence
AP6. Work with scientific explanations and theories
AP7. Connect and relate knowledge across various scales, concepts, and representations in and across domains

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Letter to the Editor

Editor, Teachers Clearinghouse for Science and Society Education Newsletter:

I am writing to address an idea presented in the article "NJAAPT addresses NGSS and AP Physics" in the Winter/Spring 2015 issue. Information is presented in the article that in the Progressive Science Initiative Program (PSI), 10th graders enroll in AP physics. I venture that if 10th graders (students 15 years old and perhaps some 16) can successfully complete AP physics, which is designed to be equivalent to physics for college freshmen, then something is not right with the AP physics course. (I think that the revised AP physics sequence is more right than ever.) I take the stand that the vast majority of high school sophomores are not intellectually ready to complete AP physics, let alone other AP courses.

This stand on my part developed when 10th graders began taking AP world history at the school at which I taught. I had been teaching AP chemistry to high school juniors and seniors for about twelve years. Once sophomores began enrolling in AP world history, enrollment in AP chemistry began to drop off. I had a conversation with a senior near the end of the year, two years after that "opportunity" was offered to 10th graders. He and I discussed his plans to complete a degree in meteorology. He was an excellent student in my honors chemistry and honors physics classes, and I expect he has been very successful in pursuing his goals. I asked him why he had not enrolled in AP chemistry. He told me that after his experience in AP world history, he had decided to not enroll in any further AP courses. He had been overwhelmed by the volume of work. The AP world history instructor presented the course as an introductory college-level course, as he should. The sophomores in his classes however, were not intellectually mature enough to handle work at that level. That situation had a near-devastating effect on the AP program at our school. Many students who would be ready to successfully complete AP courses as juniors and seniors avoided those courses.

The philosophy behind NGSS is that science course content is not as important as the process of science. I see it as a valuable move away from science courses that are wide in content, toward courses that are deep in science (and engineering) process.

The title of Robert Goodman's talk is listed in the article as "PSI Physics + NGSS = STEM Pathways for **ALL Students**." I imagine that the 10th grade students Goodman has worked with have been successful in AP physics. I'd venture that they can not be identified as part of a group identified as "ALL Students."

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AN OMISSION

The last line of the Editor's Note at the end of Bob Drake's article on page 25 of our Winter/Spring 2015 issue was inadvertently omitted. The complete note should have been "Dr. Drake based this article on a talk he presented to the Physics and Chemistry Teachers Clubs of New York on 23 January 2015."

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

Hansen Provides Climate Change Update

by John L. Roeder

Now that celebrated climate scientist James Hansen has retired from government service, he directs a program in Climate Science, Awareness, and Solutions at Columbia University's Earth Institute, which is not too far from the Goddard Institute for Space Studies he used to head. On 22 July 2015 he provided an update on climate change for the physics and chemistry teachers attending the workshops on Modeling Instruction provided by STEMteachersNYC at Teachers College, Columbia University, and others interested in what he had to say.

The climate issue is really an energy issue, Hansen began. Although the energy from burning fossil fuels enabled us to dispense with slavery by enabling the Industrial Revolution, it has also added carbon dioxide to our atmosphere and led to its warming (because it results in more energy coming in from the Sun than is emitted by the Earth). Most of the excess incoming energy leading to global warming, moreover, is going into the ocean, where it is measured by a system of ARGO floats to be several tenths of W/m^2 in imbalance. In addition, Hansen said, a forthcoming El Niño will make 2015 even warmer.

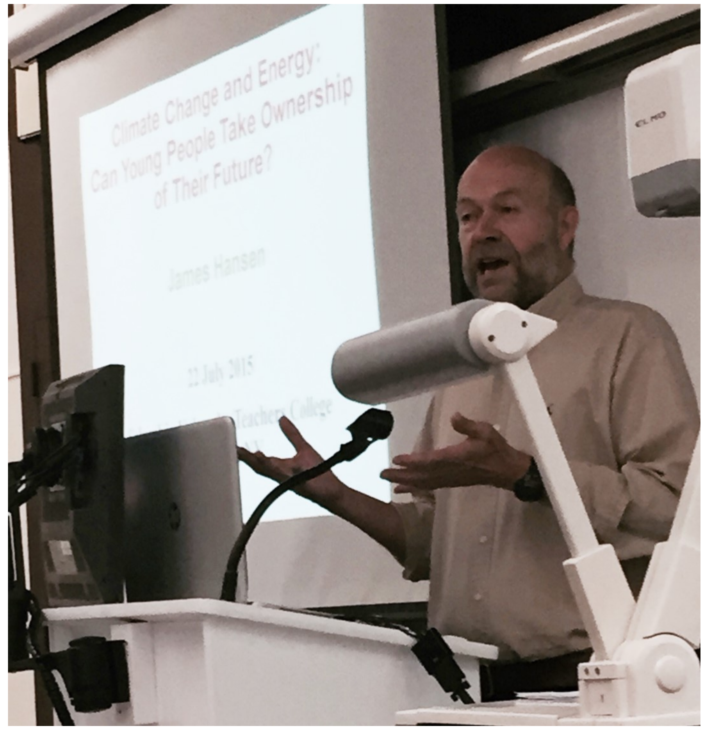
Global warming is more severe than most people realize, Hansen went on, and no one is advocating the reduction in greenhouse gas-emitting activity that is needed. Yet Earth's climate has responded only partially to the forcings applied to it.

First Area of Concern: Species Extinction

Hansen addressed three areas of special concern to him, the first being species extinction. He began with the Monarch butterfly, which he used to see around his home in larger numbers than now. It is threatened by Roundup, he observed, which kills the milkweed its caterpillars need to live. He showed a bar graph indicating decreasing numbers overwintering in Mexico since 1995, although he noted a little upturn of encouragement in 2015. Hansen also expressed concern that increased energy and acidity in the ocean are stressing coral reefs and species dependent on them.

Second Area of Concern: Ice Shelves

Hansen's second concern was the fate of the Antarctic and Greenland ice shelves, which he noted would be melted by warming oceans. Masses of both have been measured and found to be decreasing, with corresponding increase in sea level, which is more realistically described in terms of the time to double (an exponential relationship in time) than by a linear relationship in time. Hansen also noted that the Eemian sea level 120,000 years ago was five to nine meters higher, when global temperature was greater by only one degree Celsius.



Hansen also referred to a paper he and a multiauthor team have published in *Atmospheric Chemistry and Physics*, an open-access "discussion" journal, about this concern about the ice shelves and sea level rise. An online report about this paper can be found at <http://www.slate.com/blogs/the_slatest/2015/07/20/sea_level_study_james_hansen_issues_dire_climate_warning.html?wpsrc=fol_fb> and the abstract of this paper can be accessed at <http://www.atmos-chem-phys-discuss.net/15/20059/2015/acpd-15-20059-2015.html>.

Third Area of Concern: Climate Extremes

Hansen's third concern was climate extremes: more heat waves and drought, leading to an increased number of fires and more rainfall and storms, leading to an increased number of floods.

We've already burned the fossil fuels we can afford to burn without passing disastrous climate change to the next generation, Hansen continued as he approached his conclusion. Meanwhile, population continues to increase. He observed that reducing fertility requires raising living standards and that this means more energy – but he emphasized that it can't come from fossil fuels.

We need to make the cost of fossil fuels "honest," he iterated, by charging producers a fee at the source of their production. Hansen would share the income from this fee equally with all legal residents, and he expressed the feeling that this would provide an incentive for all to low-

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Science addresses Grand Challenges in Science Education

For its special section on "Grand Challenges in Science Education" in its 19 April 2013 issue, *Science* "invited experts to tell . . . what they [thought were] the most important challenges facing science education." Seven commissioned reviews addressed 20 challenges, listed as follows, with summaries following:

Michael Kremer, Conner Grannen, Rachel Glennerster, "The Challenge of Education and Learning in the Developing World" (pp. 297-300)

1. "Use technology to improve pedagogy, management, and accountability."

2. "Improve access to, and the quality of pre- and postprimary education."

3. "Develop appropriate policies for regulating and supporting the private sector in education."

These authors identified the following factors determining school attendance in the developing world: 1) conditional cash transfers (financial support to poor mothers whose children receive basic medical care and attend school regularly), 2) the distance to school and safety of home-to-school travel, 3) medical services provided at the school, and 4) the realization of the correlation between earnings and education. A chart showing the effect of a variety of measures in a variety of countries shows the most effective measures are those designed to match the level instruction to the student level of learning. The measures on this chart, however, show the results of different procedures in different countries rather than a systematic investigation of all the procedures in all countries. Perhaps that is why the paragraphs following each of the challenges ostensibly addressed by this article reflect incomplete knowledge and the article ends, "We have much more to learn."

Brian Butterworth and Yulia Kovas, "Understanding Neurocognitive Developmental Disorders Can Improve Education for All" (pp. 300-305)

4. "Develop an understanding of how individual differences in brain development interact with formal education."

5. "Adapt learning pathways to individual needs."

The US legal definition of specific learning disability (SLD) is "a disorder in one or more of the basic psychological processes involved in understanding so in using language, spoken or written, that may manifest itself in or imperfect ability to listen, think, speak, read, write, spell or to do mathematical calculations." People with SLDs need support mainly with the area of their SLD, as opposed to the intellectually disabled with an IQ less than 70, who need all-around support. SLDs affect 10% of the population.

Generally, people with more than one SLD do not have more difficulty with any one of them than a person who has only that one SLD. The five SLDs considered in this article – specific language impairment (affecting an estimated 7% of the population), dyslexia (6±2%), dyscalculia (5±1.5%), attention-deficit/hyperactivity disorder (4.5%±1.5%), and autism (1%) – have been correlated with structural differences in the brain and also distinguishing genetic characteristics. But barring prior brain or genome scans, they are most likely to be discovered when their behavior is manifest. Treatment usually depends on which SLDs co-occur, with treatment for ADHD and autism, the most highly researched, dominating.

Ton de Jong, Marcia C. Linn, Zacharias C. Zacharia, "Physical and Virtual Laboratories in Science and Engineering Education" (pp. 305-308)

6. "Create online environments that use stored data from individual students to guide them to virtual experiments appropriate for their stage of understanding."

7. "Determine the ideal balance between virtual and physical investigations for courses in different subject areas."

8. "Identify the skills and strategies teachers need to implement a science curriculum featuring virtual and physical laboratories."

The advantages of doing physical experiments are reported to be having the excitement of working with "the real thing" and confronting realistic measurement errors. Advantages of doing virtual experiments include not having to buy or set up equip-

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NRC convenes conference on STEM Teacher Leadership

The 19 April 2013 issue of *Science* contained a special section on "Grand Challenges in Science Education" (described in a separate story on page 4). A little more than a year later the National Research Council convened a conference, "One Year After *Science's* Grand Challenges in Education: Professional Leadership of STEM Teachers Through Education Policy and Decision Making." It was organized under the aegis of the National Academies Teacher Advisory Council and structured around the challenges raised in the 19 April 2013 issue of *Science*. Their challenge was to "focus on empowering teachers in science, mathematics, engineering, and technology (STEM) education at the national, state and local levels" through several articles in that issue of *Science* and to address the following issues: 1) evidence whether improvement can result from involving STEM teachers in education policy and decision making; 2) models for engaging STEM teachers in policy and decision making; 3) procedures for education officials and policy makers to understand how they can contribute to STEM teachers' work.

Former President of the National Academy of Sciences and former Editor-in-Chief of *Science* Bruce Alberts led off with a keynote address on 5 June 2014 on "Empowering Our Best Teachers: A Grand Challenge in Education." He pointed out that teachers had an important leadership role to play in implementing the NGSS (Next Generation Science Standards). He chided schools for their hierarchical nature and encouraged them to let their best teachers have more influence – his reason for creating the Teacher Advisory Council at the National Academies when he was the National Academy of Sciences President in 2002. Noting the success of a similar council in California, he called for the formation of one in every state. He also called for funding replications of what works, noting that funding only "uniqueness" is the enemy of coherence: "If all we have is innovation and no spreading of what works, then we won't have much progress."

Alberts's keynote address was followed by a panel consisting of Diane Briars, President, National Council of Teachers of Mathematics; Francis Eberle, acting Deputy Executive Director for the National Association of State Boards of Education; Cindy Hasselbring, special assistant to the state superintendent for special projects at the Maryland State Department of Education; Steven Robinson, formerly with the U.S. Department of Education and Executive Office of the President; and Terri Taylor, assistant director of K- 12 education at the American Chemical Society (ACS). Briars noted that while the public perceives teachers as working only when they're in front of students, teachers would be more productive with more time to collaborate to improve the educational system. Taylor detailed the many ways in which chemistry teachers have input into ACS educational efforts, from policy statements and curricular guides to such publications as *ChemMatters* and *Chemistry in the Community* and the newly-launched American Association of Chemistry Teachers. Hasselbring cited her experience from teaching mathematics 16 years in Michigan, which included one as an Albert Einstein Distinguished Educator at the national level and a teacher-of-the-year award at the state level, after which she became a member of the Network of Michigan Educators, where she had the opportunity to describe positive educational developments to the Michigan State Board of Education and was often called on to answer education-related questions by state government agencies or legislative committees. "People need to value the voice of a teacher," she said. Eberle noted that teachers had traveled many paths to work toward change outside their classrooms. He had two pieces of advice for those seeking to foster policy change at the state level: 1) learn how the process works, and 2) be patient for the amount of time it takes to work.

Next came a plenary address on "Teacherpreneurs: Leaders for Tomorrow's Schools" from Barnett Berry, founder, partner, and CEO of the Center for Teaching Quality (CTQ), who had already described "Teacherpreneurs" in a "perspective" from the special section of the 19 April 2013 issue of *Science*. Berry observed that 84% of surveyed American teachers "are looking for opportunities to lead that do not require them to leave teaching." He refers to "teachers who still teach regularly but have time and incentives to execute their own ideas" as "teacherpreneurs," and his CTQ works with them to realize their goals, more than 500 of them so far. "If we want more teacher leaders, we have to help more teachers, who are very busy, go public with their ideas," he emphasized.

Berry's plenary was followed by another from Suzanne Wilson, Neag Endowed Professor of Teacher Education in the Department of Curriculum and Instruction of the University of Connecticut, who spoke on "Effective STEM Teacher Preparation, Induction, and Professional Development" and had also contributed to the 19 April 2013 issue of *Science*. She began with list of features that make professional development effective which paralleled a similar list in *Science*: 1) teachers engaged and collaborating, 2) a focus on content and student learning, 3) extended over time (not isolated), and 4) coherence and alignment with relevant practices and policies. But she conceded that sometimes professional development with these features is *not effective*. She wondered whether time could be a proxy for developing trust and forming relationships needed for learning, especially for new teachers. The transition to being a teacher needs the support of expertise, she added. She went on to observe that most teacher learning does not occur in formal professional development. Rather, it occurs in all the actions

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A nuclear renaissance appears to be unlikely

An article in our Fall 2007 issue, which covered a five-day workshop on the role of nuclear power at Washington and Lee University, asked the question, "Will there be a "nuclear renaissance"? The outlook then, according to a report by Larry Parker and Mark Holt of the Congressional Research Service, was bleak, for economic reasons: without a carbon tax, electricity could be generated more cheaply by coal and natural gas.

Two years later the then president and CEO of Westinghouse Electric, Aris Candris, addressed the American Association of Physics Teachers on the same question, but provided an affirmative answer. His reasons were concerns about greenhouse gas emissions and the inability of renewable energy sources to fill baseload electrical requirements because of their intermittency.

The Tennessee Valley Authority has recently asked the Nuclear Regulatory Commission (NRC) to issue a license for their Watts Bar 2 nuclear power plant, abandoned after 55% completion in 1987 but resumed in 2007. And two nuclear plants using the AP1000 Generation III design are being built in Georgia with loan guarantees from the US Department of Energy (USDOE).

But does this constitute a renaissance? Steven T. Corneliussen, a media analyst for the American Institute of Physics who monitors three national newspapers and the weeklies *Nature* and *Science*, wrote in the 3 August 2015 online newsletter of *Physics Today* that the outlook, based upon what he has read in the *Wall Street Journal* and the *Bulletin of Atomic Scientists* (publication of the Federation of American Scientists, whose concerns are almost exclusively nuclear), is no brighter than it was portrayed eight years ago by Parker and Holt.

Among the problems cited by the *Wall Street Journal*, according to Corneliussen, were "newly abundant cheap natural gas, public perceptions since the tsunami-induced Fukushima nuclear disaster, the costs of new construction, the vexing problem of nuclear waste, and what one of the experts lamented as the absence of a 'reasonable carbon policy [that] would positively influence the economics' of nuclear power." The *Wall Street Journal* article quoted Joseph "Buzz" Miller, executive vice president of nuclear development for Georgia Power: "The promise of modular construction has yet to be seen." According to Corneliussen, the final paragraph in the *Wall Street Journal* article notes that "US utilities proposed building more than two dozen reactors five years ago before the shale-gas revolution drove down the price of natural gas and made plants that burn gas a more attractive option for the power industry."

In August 2015 President of the Federation of American Scientists Charles D. Ferguson published an online report (fas.org/wp-content/uploads/2015/08/Advanced-nuclear-technologies-report-August 2015_final_version.pdf), *Moving Advanced Nuclear Energy Systems to Global Deployment*. After reviewing the how early nuclear reactor design was locked into that of today's prevalent light water reactors because of their need to produce plutonium and propel submarines, Ferguson cuts to the internationally pooled efforts beginning January 2000 in the Generation IV International Forum (GIF), which led to a 2002 roadmap with four main goals: sustainability, safety and reliability, economic competitiveness, and proliferation resistance and physical protection. (This is available online at <www.gen-4.org>.) Ferguson notes that the GIF winnowed six nuclear design concepts from almost 100, each needing to meet the tests of viability, performance, and demonstration, with one reason for greater efficiency being replacement of today's steam Rankine cycle with more efficient Brayton power cycles. The six design concepts are as follows:

1. *Gas-Cooled Fast Reactor* (GFR) – a fast neutron reactor cooled by helium with a closed fuel cycle, developed by General Atomics, with efficiency expected from 48% to 53%, due to high operating temperature. A one-tenth scale model is being studied by a consortium of eastern European countries, and the performance demonstration phase may be reached by 2025.

2. *Lead-Cooled Fast Reactor* (LFR) – a fast neutron reactor running at atmospheric pressure, at temperatures above the 327°C boiling temperature of the coolant (lead or a lead-bismuth combination), with more than 42% efficiency. Unlike liquid sodium, lead doesn't react with water, and it also shields against radiation, but special procedures would be needed to dispose of it safely. Problems were experienced with lead/bismuth-cooled reactors in two Russian submarines, and other design variations are being studied by the U.S., China, Korea, Japan, and some European countries. The LFR is being developed as a 25 MW unit which can be used modularly.

3. *Molten Salt Reactor* (MSR) – has nuclear fuel either dissolved in or coated and surrounded by a molten fluoride salt coolant which would also keep the environment free of radioactive particles. This design originated in the 1950s in the course of trying to develop a reactor safe for aircraft; it runs at atmospheric pressure. The MSR's use of $^{232}Th/^{233}U$ cycle makes it more proliferation resistant than ^{238}U-reactors. The ability of the molten salt to trap all radioactive particles would greatly facilitate management of wastes

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nuclear

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from the MSR. A variation of the MSR is the pebble-bed advanced high-temperature reactor (PB-AHTR), which could be commercialized by the mid-2020s.

4. *Sodium-Cooled Fast Reactor* (SFR) – not a new technology but one which has stumbled in the U.S., France, and Japan because coolant leaks lead to fires when sodium reactors with water or air. Because of limited space for nuclear waste storage, Korea is most likely to move forward on SFR research as a way to close the nuclear fuel cycle. Russia has the greatest experience with SFRs among nations still interested in them.

5. *Supercritical-Water-Cooled-Reactor* (SWCR) – uses supercritical water as a coolant. In its supercritical phase water has the same density in liquid and vapor states, so is ready to be fed directly to a turbine without the need for steam generators, steam dryers, recirculation pumps, and a secondary cooling system. Without the need for all this equipment, the SWCR can be made smaller than a pressurized water reactor (PWR, one variant of today's light water reactor), with an estimated efficiency of 45%. But maintaining supercritical water requires 15 times the pressure of a PWR and backup power. The fast neutron version's positive void coefficient means that a vacuum would lead to uncontrolled heating. Few countries are pursuing the SWCR.

6. *Very-High Temperature Reactor* (VHTR) – evolved from earlier high-temperature (helium) gas-cooled reactors, can provide hydrogen for fuel cells and heat for processes as well as electric power, with 47% efficiency if operated at 850^{o}C and 50% at 950^{o}C. Its strong negative temperature coefficient of reactivity and high heat capacity of its graphite core are strong safety features that make unnecessary off-site power to survive catastrophes such as happened at Fukushima. This design is the most likely of the GIF designs to be commercialized.

While these design concepts are being developed into the nuclear power plants of the future, the following developments, largely focusing on small modular reactors (SMRs), are occurring now:

1. Building on the present design of PWRs, Babcock and Wilcox has designed the mPower advanced light water reactor, an integral PWR (iPWR) with passive and other innovative safety designs in a self-contained 180 MW electric module (this is why the design is "integral"). NuScale seeks to commercialize a scalable 50 MW electric iPWR design using 4.95% enriched uranium in a 24-month refueling cycle (a higher enrichment percentage than in present-day light water reactors, which also have a shorter refueling cycle). KAERI in Korea is developing SMART (System-integrated Modular Advanced ReacTor), which is a PWR capable of 100 MW electric or 90 MW electric plus 40,000 tons of desalinated water per day.

2. Developments in liquid sodium reactors include the PRISM design developed by GE Hitachi for an 840 MW thermal fast reactor, touting its advantage of consuming transuranic materials, and the 4S (SuperSafe, Small, and Simple) fast reactor which can operate 30 years without refueling – in 10 MW electric or 50 MW electric sizes.

In the timeframes envisioned by the Nuclear Regulatory Commission, the near term will involve licensing Generation III reactors using iPWR designs, and the longer term will add in liquid metal-cooled reactors. Beyond that, in the horizon timeframe, one or more of the six design concepts described above will make its debut, and the beyond-the-horizon timeframe will see the advent of projections from the April 2010 Department of Energy Research and Development Roadmap and January 2012 recommendations of the Blue Ribbon Commission on America's Nuclear Future (covered on page 5 of our Fall 2012 issue). Because the Nuclear Regulatory Commission's experience has largely been with light water reactors, the greater the difference between the materials or structure of a new reactor design from that of light water reactors, the longer will be the time needed to evaluate it.

Ferguson reaches the following six conclusions about the future of nuclear energy in the U.S.:

1) Government support is necessary to develop new nuclear energy technologies.
2) International cooperation is "vitally important in R & D."
3) "Continued and expanded effort on multinational regulatory work is needed to harmonize regulatory standards . . . ."
4) SMRs are attractive, especially those that can do more than generate electric power.
5) Energy efficiency greater than 40% will make nuclear power more competitive, also the ability to switch from base load to peak load.
6) Governments and industry need to plan knowledge management and creation and to train the workforce that will run the next generations of nuclear power plants.

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A Pathway to Learning Using Myths and Stories

by Jane Konrad

From before the ancient Greeks, myths and folklore served to help mankind understand the world around them, changing according to cultural beliefs. The questions and themes addressed remained essentially common over time and geography. Stories and narrative fantasies are powerful ways for students to explore the world and to understand themselves in a social context that is safe and often familiar. Sometimes stories are the only way we can make sense of the world. For younger children especially, stories are avenues for helping establish concepts and ideas.

A recent ebook addressing urban environmental education [A. Russ (ed.), *Urban Environmental Education* (Cornell Civic Ecology Lab, Ithaca, 2015)] contains a chapter on storytelling that highlights the following assets:

- Storytelling engages diverse, highly sophisticated urban audiences; it enables listeners to create connections between their experiences inside classrooms, in familiar city centers, and urban parks.
- Environmental educators can use active storytelling to generate interest, excite discussion, and create understanding of complex cultural and environmental issues.
- Active storytelling challenges students to use their imagination and creativity to engage in more sustainable lifestyles and environmental stewardship.

The Pittsburgh Regional Center for Science Teaching (PRCST) has offered professional development workshops that help educators utilize the myths of classical Greece, Rome and other cultures as pathways to science.

Consider the example of the myth of Persephone and Demeter to explain the reason for seasons. Using this myth as a basis, academic studies are stimulated in the areas of seasonal changes, climate, Earth's orbit/tilt, solar system, and biodiversity. Even in limited educational situations, the interest and observation of seasons can offer excellent study areas. The study of seasons easily connects to plants, ecosystems and even our food systems. It flows into understanding of our solar system, Earth's tilt on its axis, geography, biodiversity of flora and fauna, and cultural diversity. Some essential questions might be 1) Where are we in the solar system? 2) Explain how our Earth goes through seasons. How can we identify, characterize, demonstrate these? 3) What is climate? Weather? What are their causes and impacts?

Amazingly, even with many years of curricular presentations, students seldom truly understand the seasons. The DVD "Private Universe" [*A Private Universe - Annenberg Learner*, learner.org/resources/series28.html] illustrates how Harvard graduates never developed an understanding of the reason for seasons. This DVD provides a graphic way to introduce the subject and the myths. A good explanation and examples can be found in "The Real Reasons for Seasons: Sun-Earth Connections" [*GEMS (Great Explorations in Math and Science) Guide Book from the Lawrence Hall of Science*, Grades 6-8, 2000] along with related activities. This book addresses misconceptions rampant in the minds of so many people.

As the seasons progress, elementary students can study changes in the ecosystems and their biodiversity. Higher level students may carry their research deeper into the symbolic meanings or underlying moralities expressed in the story. The study of geology, related customs, and ethnic variations may all enrich work in this area. For relevance, climate studies along the geological timeline might include changes today and potential causes of those changes (seasons-weather, flora and fauna), taking note of the Keeling Curve (the increase of CO_2 and its rate over time) and the IPCC (Intergovernmental Panel on Climate Change) reports. These studies can all follow the charge of including rigor, relationships, and relevance – the new 3 Rs!

For current relevance, National Geographic published a recent finding: "Greek archaeologists have discovered the image of a young, red-haired goddess being swept off to the underworld inside a 2,300 year-old tomb near the ancient site of Amphipolis in northern Greece. Identified as Persephone, daughter of Zeus, the goddess portrayed on a mosaic floor provides a key new clue to what in recent months has become a much publicized mystery: Who was laid to rest in the immense, marble-walled tomb 61 miles (99 kilometers) northeast of the Greek city of Thessaloniki?" [Heather Pringle, National Geographic: news.national geographic.com/news/2014/10/141018-amphipolis-tomb-persephone, 2014]

The emphasis on encouraging creativity in students is easily integrated in the use of myths and stories. Examples include fifth grade level students creating playing cards symbolizing the traits of Greek gods or goddesses, where they need to research, understand symbols and their representations, and elements of design as they construct the card. [Patti Drapeau, *Sparking Student Creativity* (ASCD, Alexandria, VA, 2014)] Understanding symbols actually underlies our learning to read. As Maryanne Wolf notes, "Reading involves the acquisition on an entire symbolic code, which is both visual and verbal". [Maryanne Wolf, "Balance technology and deep reading to create biliterate children," *Phi Delta Kappan* (November 2014)].

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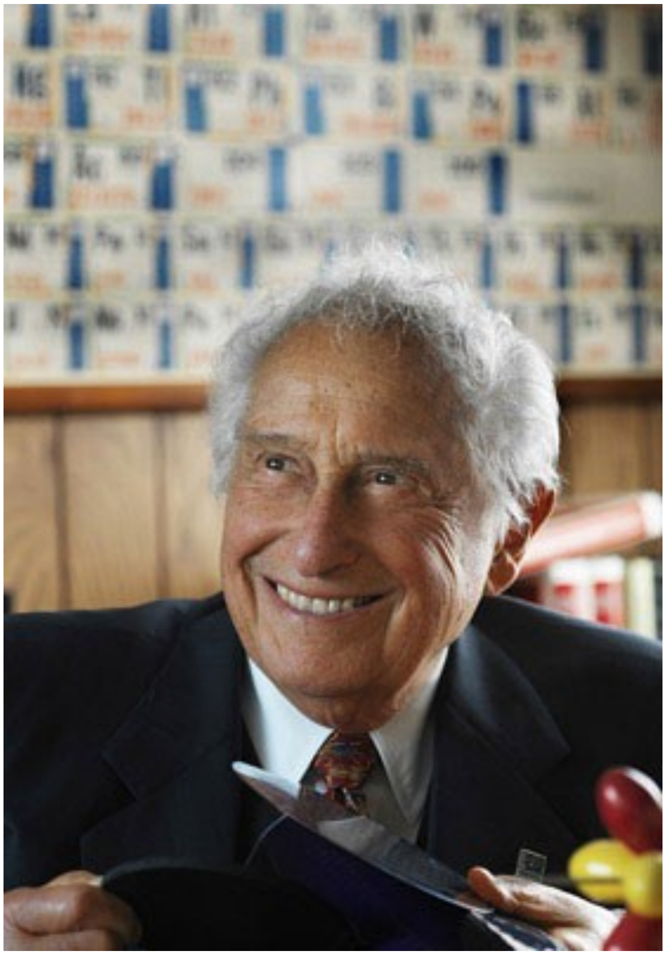
A profile in American Innovation

by Greg Good, Director, Center for History of Physics



Stanford R. Ovshinsky, August 2005. Photographed by Glenn Triest for *Style* magazine. Licensed under CC BY 3.0 via Wikimedia Commons.

Stanford Ovshinsky was an American scientist who approached invention with intuition and drive. He founded Energy Conversion Devices, an AIP Corporate Associate, in the 1960s and developed innovative new products that have spurred entirely new industries. The AIP community learned more about Ovshinsky, his life, work, and impact at its most recent Lyne Starling Trimble Science Heritage Lecture, given by Dr. Lillian Hoddeson, a well-known historian in the physical sciences.

Hoddeson spoke movingly of the enthusiastically unconventional scientist and entrepreneur Stanford Ovshinsky, whose biography she is currently writing. Ovshinsky was important in establishing the investigation of amorphous and disordered materials, but he was not bound by disciplinary identification. Hoddeson quoted Richard Zallen (professor emeritus of physics, Virginia Tech) as saying: "What Stan does is not science. It's more interesting than science."

Hoddeson described Ovshinsky's intuitive and visual approach, his willingness to forge ahead with trials and experiments based on his visualizations and pattern recognition, and his occasional dismissal of the lack of a theory. He and his associates took the amorphous and disordered materials he had created and sought to invent technologies using them. Over decades they developed nickel metal hydride batteries, thin-film solar panels, the Ovitron (the first amorphous switch) and then the threshold switch, and phase-change memory.

Hoddeson traced Ovshinsky's unorthodox methods to his upbringing. He was born in Akron, OH, in 1922, where his mother and father had settled after emigrating from Lithuania and Belarus. His father collected scrap metal from factories, and Stan's first jobs in his teens were as a tool maker and machinist. His ideas came from materials and processes. He was always at home in industrial settings.

During World War II, Ovshinsky conceived of his first successful invention, a high-speed, center-drive lathe, while working in tool shops for the rubber industry. He established his first company, a machine shop, to develop this lathe, patent it, and sell it. In the 1950s, he directed research for the Hupp Motor Company and broadened his interests to include machine intelligence and cybernetics. He and his brother founded another company, General Automation, with this general interest, which they combined with new techniques to produce an amorphous, thin-film switch, the Ovitron.

In 1960, Ovshinsky — a serial entrepreneur — started the company Energy Conversion Laboratory (ECL) with the goal of solving an energy crisis that would not be generally recognized until a decade later. The working-class Jewish immigrant community in his Akron years had instilled in him a dedication to solving social problems. He always saw his work in science and invention as aimed at solving problems important to society. ECL developed electronic memory, new batteries, solar cells, and more. Devices in our pockets and on our desktops owe their existence in part to this pioneering work.

Ovshinsky died in 2012.

(*Editor's Note*: Greg Good is the Director of the Center for the History of Physics of the American Institute of Physics. His article is reprinted with permission from the 27 July 2015 issue of *AIP Matters*.)

Club of Rome launches *2052: the world in 40 years*

It's been more than twenty years that this *Newsletter* reported on Donella Meadows's talk on *Beyond the Limits*, a twenty-year retrospective and update of The Club of Rome's 1972 study, *Limits to Growth*, which projected the future global interaction among population, food, natural resources, pollution, and industrial output. Meadows's talk was covered in our Winter 1993 issue, and the Spring 1993 issue contained a review of the book, which she wrote with Dennis Meadows, and Jørgen Randers.

A recent visit to <www.clubofrome.org>, website of The Club of Rome, revealed that the Club, which was founded in 1968, continues to uphold its mission "to undertake forward-looking analysis and assessment on ways forward to a happier, more resilient, sustainable planet." Their current efforts are focused on their *2052: the world in 40 years* campaign, "to stimulate ideas on future options to shape the world in a sustainable way," for which Randers has written *2052 – A Global Forecast for the Next Forty Years*.

Another report to The Club of Rome that is part of the 2052 campaign is *Bankrupting Nature: Denying our Planetary Boundaries*, written by Anders Wijkman and Johan Rockström, and published by Routledge in 2012. (ISBN 978-0-415-53969-2) Its key messages are reproduced in the box below.

Bankrupting Nature's 12 key messages

1. Scientific evidence is overwhelming that human pressure on the planet has reached a point that poses major risks for future welfare and prosperity. Science indicates that we are transgressing planetary boundaries that have kept civilization safe for the past 10,000 years. Accelerating human activity is now the most significant driver of global change, propelling the planet into a new geological era, termed the Anthropocene. There are now so many of us, using so many resources, that we are disrupting the grand cycles of biology, chemistry and geology. We can no longer exclude the possibility that our collective actions might trigger tipping points, risking drastic and irreversible consequences for human communities and ecological systems.

2. The sustainability crisis is manifested through social, financial, economic and environmental problems now playing out globally. We are faced with a set of serious challenges, driven by wasteful production and consumption, skewed trading and subsidy systems, and persistent and recurring financial crises. Gaps are widening, between nations and within nations. Unemployment is endemic and rising, particularly among the young. The financial system is increasingly divorced from the real economy. Moreover, it has miserably failed to generate the necessary investments to move society towards sustainability.

3. The concept of "planetary boundaries" provides a science-based framework that can guide us through the transition to sustainability. The aim must be to strengthen the planet's resilience and its ability to continue providing a "safe space" for human development and wellbeing. A number of critical issues have to be addressed, such as climate change, depletion of stratospheric ozone, biodiversity loss, changes in land and freshwater use and interference with nitrogen and phosphorus cycles, air pollution, chemical pollution and ocean acidification.

4. We urgently need to adopt a more holistic approach to human development. It is no longer possible to deal with one issue at a time. Today´s – mostly vertical – scientific endeavors and approaches might give the impression that there is a significant degree of uncertainty within the scientific community. However, if we put "all our cards on the table" about global environmental risks, the 'risk panorama' is overwhelmingly clear. The interplay between the atmosphere, the oceans and the land-based ecosystems is of particular significance and calls for a properly integrated, solutions-oriented science for global sustainability.

5. Climate denial poses a serious challenge. It has several causes, such as vested interests and ideological and cultural barriers. To counteract the advocates of denial, new ways of communicating with the public must be explored – *e. g.*, by mobilizing the behavioral sciences – to complement pure scientific facts and data.

6. The Earth has had a remarkable capacity to buffer the expansion of human activities – allowing continued economic growth, despite serious ecological decline. The economy of today is built on the premise that material consumption can expand indefinitely. However, science tells us that this is not possible given the combination of high and increasing pollution levels, collapsing ecosystems, a changing climate and resource constraints. De-growth is no solution either, as it would mean the collapse of our social, financial and economic systems. The growth dilemma can only be addressed – and resolved – through an in-depth, value-based discussion in society about the overall objectives of development in the future. A precondition for charting out a new course will be a radically changed economic policy framework.

7. The short-term nature of both politics and markets constitutes the greatest obstacle to addressing today's serious threats to sustainability. The same goes for the tendency to focus on "one issue at a time." The financial crisis is not about money alone. To repay and service all the debts will require substantial wealth generation, which can only happen with the help of major

inputs of energy and materials. Prices for energy and most commodities are on the increase, which will make the repayments of debts increasingly difficult. The only possible solution to this problem – and, as well, to the challenge of climate change and ecosystem decline – ought to be a significant increase in energy and resource efficiency. This, in turn, can only be achieved by applying a systems perspective – by merging the agendas of economics and finance with the agendas of climate and energy security, ecosystem decline and resource constraints.

8. To change course, priority should be given to the following measures:

- stop using GDP growth as the main target of development;
- taking nature into account, by assigning a value to ecosystem services and biodiversity;
- implementing a tax reform: reducing taxes on labor and raising taxes on resource use;
- removing all environmentally harmful subsidies;
- using public procurement proactively for sustainability objectives;
- reducing the risk of financial crisis by significantly increasing the leverage ratio for banks and financial institutions;
- obliging financial institutions to report their risk exposure in terms of carbon investments;
- rethinking both the system of quarterly reporting, and the compensation system for financial institution employees, currently based on short-term performance ;
- introducing long-term planning by rethinking the system of discounting of future values;
- rethinking business models so that revenue can be earned through performance and high-quality service rather than simply selling "more stuff."

9. It has been suggested that 'decoupling' the link between economic growth and the use of energy and materials will produce 'green' growth. The results so far have been poor, however, as the gains are frequently eaten up by expanding economies. A way out of this conundrum would be to focus on *effectiveness – i. e., doing the right things* – rather than on *efficiency alone*.

The main thrust ought to be for a *circular economy*, where products are designed for longer use, reuse, disassembly and refurbishment. Materials should be reused and recycled to the extent possible, thus reducing the demand for mining and new manufacturing. A bonus effect would be the creation of many new jobs within the service organization needed at local level.

The circular economy ought to be promoted by the adoption of binding targets for resource efficiency, increased taxes on the use of virgin materials and priority given to sustainable innovation and design.

10. We need strategies for planetary stewardship. Solutions and policies must pass through a "nine billion filter," –*i.e.,* they must work for a future population of at least nine billion people. This means efficiency gains in delivering services to the order of a factor of five or more, the building of a low-carbon and resource-efficient infrastructure as well as the systematic pursuit of systems-based and transformative solutions.

11. Give enhanced priority to population. Birth rates continue to be very high in many of the least developed countries, making poverty eradication more difficult. But population numbers have a great bearing on sustainability as well. It is often claimed that world population growth is not a problem from the point of view of sustainability, as poor people use fewer resources and have a smaller carbon footprint. This is a very short-term view. Every human being born should have the right to a decent standard of living. That in turn means sufficient access to natural resources and thus an increasing footprint. Hence, every effort should be made to stabilize the world population, primarily through the provision of education for girls, access to clean energy and family planning services.

12. While efforts to improve global governance have had very limited success so far, the world must continue to work for global agreements. Parallel to that the pursuit of local solutions should be greatly scaled up, led by individual governments, cities and regions, companies and civil society organizations. Development cooperation must be closely linked to environmental and climate efforts. The replacement of the Millennium Development Goals for Sustainable Development Goals, as suggested at the Rio+20 Conference, would be a move in the right direction.

nuclear

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Ferguson's report clearly shows that a roadmap for nuclear energy in America's future has been developed. But without government support it is unlikely that the path charted by the roadmap will be traveled. All the problems impeding a nuclear renaissance in 2007 are still with us, and probably make the situation still more dire: Not only can natural gas generate electricity more cheaply than nuclear fission, but the availability of natural gas from fracked shale makes it even cheaper, and gas-generated electricity emits fewer greenhouse gases than coal-generated electricity. Moreover, there still are no mechanisms to increase the cost of electricity generated from fossil fuels with a carbon tax.

Influencing Geoscience Policies on the Hill

by Michael J. Passow, Earth Science Correspondent

Like it or not, much of our country's policies affecting the geosciences result from decisions made by Congress. Very few Senators or Representatives have extensive background in the Earth and Space Sciences. So they usually receive direction for crafting bills and voting from their legislative aides. How do these people make their decisions?

In many cases, it's through discussions with groups of visitors to their DC and District offices. At the end of September, I participated in the American Geosciences Institute (AGI)'s Congressional Visitation Day (CVD). On 29 September, I joined about 80 representatives from dozens of professional societies at a workshop to learn how Congress works, how to conduct congressional visits, and about relevant legislation, federal agencies, and programs. At the end of the workshop, we met with others who would be in our group to craft and practice our messages with geoscience policy staff. My New York/ New Jersey team included another educator from NJ and a Ph.D. candidate from NY, matched with an American Meteorological Society staffer.

The next day, we met with legislative aides in the offices of Senators Booker, Menendez, and Gillibrand, and Representatives Pascrell, Lowey, Slaughter, and Hanna. Each meeting ran from about 15 to 30 minutes, and was probably one of six or seven scheduled that day for the Aides. A meeting generally includes brief introductions of the team members, exchange of business cards, and then the key "Message/Ask." We have very limited time to connect with the Aide so that, when appropriate information about issues or proposed legislation arises, they will remember to contact us.

My 2015 "message" included that strong and sustained federal investments in geoscience will

- Promote innovation and create jobs
- Advance economic and national security
- Strengthen global competitiveness and severe hazards preparation
- Create knowledgeable future decision-makers

Based on that, my "Ask" was to

- Support robust federal investments in geoscience research
- Support for programs that enhance teacher quality and retention
- Support for programs that enhance science (STEM) education, especially in public schools with minority populations

It appeared that all of the legislators whose offices we visited are already favorably inclined to the message, although as no specific pertinent bills are coming soon, the main way to gauge our success is to wait until we receive future contacts.

Nearly thirty other Geoscience CVD groups met with aides and, if they were fortunate, the Senators and Representatives themselves. (We did shake hands with Senator Booker, but he dropped by between votes to meet with a group from the National Boys and Girls Clubs.) CVD is an annual event organized by AGI and associated societies.

But this is not the only way to influence geoscience decisions on the Hill. AGI has organized a Geoscience & Critical Needs Working Group to develop informational materials which share scientific expertise and perspectives on such topics as

- Water supplies
- Energy and power
- Resiliency to natural hazards
- Healthy soils
- Providing raw materials
- Confronting climate variability
- Mitigating threats to the oceans and coasts
- Managing wastes

AGI recently issued an updated report, "Geoscience for America's Critical Needs: Invitation to a National Policy Dialogue." It can be downloaded at <http://www.americangeosciences.org/policy/critical-needs>. Each of the topics included is discussed in one-pagers which basically have a "Message/ Ask" format. Printed versions are made available for AGI leaders and staffers, and others, who will visit legislative offices throughout the year, especially as pertinent bills develop.

AGI is a network of more than 50 associations representing over 250,000 geoscientists with a diverse array of skills and knowledge of our planet. The Institute provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment. The AGI website, <http://www.americangeosciences.org/>, provides many valuable resources.

In addition to the efforts described above, the AGI Education and Outreach Program www.americangeosciences.org/education) sponsors the annual Earth Science Week, partners with commercial publishers to offer textbooks and other resources, and provides professional development opportunities. AGI

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AIP lessons on Women and African American Physicists

The Center for History of Physics of the American Institute of Physics has developed lesson plans to teach about women and African Americans in physics and other physical sciences. There are almost 20 in each category, with those for Women available online at <https://www.aip.org/history-programs/physics-history/lesson-plans-women-physics-astronomy> and those for African Americans at <https://www.aip.org/history-programs/physics-history/ lesson-plans-african-american-physics>.

The titles of the lesson plans for African Americans in Physics, Astronomy, and Allied Sciences are as follows:

1) African American Physical Scientists and the Military Objective
2) African Americans in Astronomy and Astrophysics
3) African Americans and the Manhattan Project
4) Ronald Mallett's Quest for a Time Machine
5) African American Scientists at BellLabs
6) Elmer Imes and Spectroscopy
7) Jim Gates and the quest for How Nature Works
8) Astronomy and the Underground Railroad
9) Edward Alexander Bouchet (first African American to receive a PhD, in 1876)
10) Four Pioneering African American Astronauts
11) National Society of Black Physicists
12) African Mythologies
13) Physical Science at Historically Black Collleges
14) Elmer Imes and civil Rights of Juliette Derricotte
15) Herman Branson and Science Training of African Americans in World War II
16) African American Inventors
17) Tuskegee Weathermen
18) African Americans in Physics in the 1960s
19) Katherine Johnson, Christine Darden, and "West Computers"

The titles of the lesson plans for Women in Physics, Astronomy, and Related Disciplines are as follows:

1) Scientific Couples in Physics and Astronomy (Ayrtons, Campbells, Curies, Herschels, Hoggs, Joliot-Curies, Kirches, Maunders)
2) Williamina Paton Fleming: Astronomer
3) Experiences of Contemporary Women Astronomers
4) Inge Lehmann: Danish Seismologist
5) Jocelyn Bell Burnell: Radio-Astronomer
6) ECHO Women in Science&Engineering Project, George Mason University
7) Women Not Awarded Nobel Prizes (Meitner, Wu, Blau, Bell Burnell)
8) Women Who Helped Win World War II (*The Girls of Atomic City*)
9) Ellen Dorrit Hoffleit: Astronomer
10) Lisa Meitner: Nuclear Physicist
11) Women of NASA: Eigenbrode, Metcalf-Lindenburger, Petro, Noble, Amer
12) Almost Astronauts (Mercury 13)
13) Anti-Nepotism Discrimination (Mayer, Gaposhkin-Payne)
14) Subtle Discrimination
15) L-Oreal UNESCO Women in Science Laureates
16) Invisible Scientists
17) Effect of World War II on Women Scientists' Careers
18) APS Woman Physicist of the Month (since Jan 2012)

"Science Evangelist" receives Gemant Award

After receiving the Gemant Award from the American Institute of Physics for making significant contributions to the culture, artistic, or humanistic dimension of physics, Ainissa Ramirez spoke to the summer meeting of the American Association of Physics Teachers in College Park, MD, on 28 July 2015 about "Our Sputnik Moment in STEM Education." As Sputnik motivated the U.S. to take great strides to make great strides to improve science education in 1957, Ramirez – who refers to herself as a "science evangelist" – called upon policy makers, teachers, parents, and mentors to make similar strides in STEM education in order to preserve America's position as a global leader in technology and innovation.

But, mindful of the thousand materials that Edison had to test before he found the one that met the requirements of a successful light bulb filament, Ramirez cautioned that there would be no quick fix, that patience and confidence would be required and that we need to propagate a culture based on these characteristics in the next generation.

Moreover, the next generation of workers in STEM fields will need to be a better representation of the demographics of our country, Ramirez went on. Different degrees of opportunity, race, and socioeconomic status are not indicators of ability, she said, and it is important that STEM workers from diverse backgrounds be a key element in America's overall success in STEM fields.

(*Editor's Note*: Information for this report was extracted from *AIP Matters*, the electronic newsletter of the American Institute of Physics, for 10 August 2015.)

Grand Challenges

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ment, the ability to measure macroscopically "unobservable" phenomena, the ability to "observe" more in a given amount of time, the ability for a teacher to follow student research paths and offer critiques, and the ability to investigate situations different from physical reality. No difference on test results was measured for students doing physical *vs.* virtual labs in a wide variety of cases, except for young children first experiencing a balance – there nothing could trump the value of tactile experience. Students doing virtual optics and chemistry labs outperformed students performing the equivalent physical labs (where the chemistry data were messy). In other cases a combination of physical and virtual experiments was found to lead to better student test performance than physical or virtual experiments alone.

Suzanne M. Wilson, "Professional Development for Science Teachers" (pp. 310-313)

9. "Identify the underlying mechanisms that make some teacher professional development (PD) programs more effective than others." (pp. 310-313)

10. "Identify the kind of PD that will best prepare teachers to meet the challenges of the Next Generation Science Standards (NGSS)."

11. "Harness new technologies and social media to make high-quality science PD available to all teachers."

Wilson cites five characteristics of effective professional development (PD) identified for research: "focusing on specific content," "engaging teachers in active learning," "enabling the collective participation of teachers," "coherence," "sufficient duration (both in intensity and contact hours)." She also notes five additional factors contributing to effective PD: activities close to practice, physical and psychological comfort, immersion in inquiry experiences and witnessing models of inquiry teaching, curriculum materials educative for teachers, and direct instruction in teaching specified in innovative materials.

After describing specific examples of current PD and their consequences, Wilson turns to the future need to explore how the five characteristics of effective PD work to produce teacher learning. She also cites five supports for change – administrative leadership, teacher quality, parent-community ties, student-centered learning environments, and instructional guidance – and notes that "schools with strength in three to five of these supports were 10 times more likely to demonstrate significant learning gains (as measured in mathematics and reading)." Because the NGSS call for an unprecedented new way of teaching science, unprecedentedly new PD must be developed to train teachers (at a cost of $1 to $4 billion over several years).

Noah Weeth Feinstein, Sue Allen, Edgar Jenkins, "Outside the Pipeline: Reimagining Science Education for Nonscientists" (pp. 314-317)

12. "Help students explore the personal relevance of science and integrate scientific knowledge into complex practical solutions."

13. "Develop students' understanding of the social and institutional basis of scientific credibility."

14. "Enable students to build other own enduring, science-related interests."

These authors report that there is no evidence that providing the same high school science education both to students who will become future scientists and to those who will not has "enhanced people's ability to function in a world where conflicting health advice clutters the Internet, research is filtered through political screens, and the media strips content from scientific claims." Yet other research has identified "competent outsiders" who have been able to "identify relevant pieces of science and understand their local or personal implications without relying on schoolbased knowledge of particular scientific methods or concepts." These authors seek to develop a "plan for cultivating competent outsiders."

"There are many different 'publics' for science," they continue, "each with different concerns and resources for making sense of the world" – *e.g.*, "six demographically distinct groups of Americans who respond to news about climate change in predictable, group specific ways." "Although some people are interested in science for its own sake, many engage with science in response to situation-specific needs and tend to be interested in science only insofar as it

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Grand Challenges

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helps them solve their problems." "Context shapes the process of engagement, and scientific principles take on different significance in different contexts. . . . ." Moreover, those seeking scientific information to solve a personal problem may be bewildered by the diversity of methodologies employed by a diversity of scientific fields.

"What use is it to know a canonical collection of facts or an allegedly generic scientific method if people engage with specific pieces of science in highly contextualized ways?" they ask. It may be necessary to reconsider how people "know science, think scientifically and appreciate science."

"*Knowing Science: From Knowing the Textbook to Assessing the Science You Need"*: "No set of scientific concepts and principles, no matter how carefully chosen, will be sufficient preparation for future engagement with science. This is a consequence of the unpredictable path of scientific progress, shifting social and political demands on scientific knowledge, and the variety of contexts and motives that drive public engagement." A person will rely on prior scientific knowledge as much as possible when confronting new scientific knowledge but beyond that will consult other sources (especially the Internet) as needed. But because such encounters are not always successful, "science education should prepare more students to access and interpret scientific knowledge at the time and context of need." One way to do this is Problem Based Learning (PBL, developed in medical schools), which can "foster metacognitive skills that underlie self-directed learning." Related approaches are STS and Place-Based Education, which "mimic public engagement with science . . . using authentic social and practical problems that cannot be defined in purely scientific terms." "Educators and researchers should work together to adapt problem-focused pedagogies for a broad range of audiences, develop appropriate assessments and – critically – find the most productive balance between these strategies and other means of presenting disciplinary science content."

"Thinking Scientifically: From Practicing Science to Judging Scientific Claims": By listing eight "distinct but interconnected" science and engineering practices, the NGSS reject "the empirically dubious notion of a single scientific method." Yet the emphasis of these practices on the scientist's perspective precludes "cues that help outsiders make informed judgments," because outsiders rarely need to retrace the science practices to get the information they need. Science education can help develop competent outsiders with lessons on such science practices as scientific argumentation and communication and "the social-political nuances of 'how science really works.'"

"Appreciating Science: From Positive Feelings to Deep and Durable involvement": Though many students lose interest in science over time, some subsequently find a reawakened interest in an aspect of science which they satisfy by a wide variety of venues (*e.g.*, museums, science cafes) that provide experiences like project-based learning. Schools should do whatever they can to encourage this, for the satisfaction it brings adds confidence in their ability to learn science and thereby strengthens their interest in it.

Learning to be a competent outsider requires accessing and interpreting "science in the context of complex, real-world problems." This means more experience like PBL, which would "result in a better balance between pre-professional science education and science education for nonscientists." "Those outside the pipeline . . . would benefit most from reform. Serving their needs requires a different sort of activism, and new attention to evidence about how, when, and why people interact with science."

M. Suzanne Donovan, "Generating Improvement Through Research and Development in Education Systems" (pp. 317-319)

15. "Shift incentives to encourage education research on the real problems of practice as they exist in school settings."

16. "Create a set of school districts where long-standing, multidisciplinary teams work together to identify effective improvements."

17. "Create a culture within school systems that allows for meaningful experimentation."

Knowing what to do to solve a problem is a *design* challenge. *Doing* what we need to do to solve a problem is an *implementation* challenge. When implementation solves a problem perceived by the implementers, the implementation challenge is accepted. When the implementation solves a problem

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Grand Challenges

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perceived by persons who are not expected to do the implementation, accepting the implementation faces hurdles.

"Translational research" is "intended to make advances in research knowledge usable for practice." "A National Research Council Committee . . . concluded that, in contrast to medicine and agriculture, education researchers have few opportunities to identify the specific problems of practice that can serve as productive starting points for programs of research and development." Education researchers need to "spend time in practice settings more routinely in order to observe and articulate problems of practice for which research knowledge can contribute potential solutions." Once a best practice is identified, a solution for implementing it must be developed.

"The many ways in which a system acts to reject or undermine an intervention must itself be treated as a set of problems to be solved." Researching the obstacles to implementing the best practices for treating adolescents hospitalized for cystic fibrosis came up with a list of 30 such obstacles.

If an effective solution to a problem is found, one cannot expect that it will transfer on its own to similar problems in other areas. Motivations are discipline-dependent: monetary incentives for economists, cultural and social norms for sociologists, cognitive and emotional processes for psychologists. Reducing "lag time between the initial investment in research and change in practice . . . is particularly important if practitioners are to see value in research."

James W. Pellegrino, "Proficiency in Science: Assessment Challenges and Opportunities" (pp. 320-323)

18. "Design valid and reliable assessments reflecting the integration of practices, crosscutting concepts, and core ideas in science."

19. "Use assessment results to establish an empirical evidence base regarding progressions in science proficiency across K-12."

20. "Build and test tools and information systems that help teachers effectively use assessments to promote learning in the classroom."

"Educational assessments ought to be statements about what scientists, educators, policy-makers, and parents want students to learn and become." It is important for these stakeholders "to develop a shared perspective in what constitutes high-quality and valid science assessments across K-16+ if assessments are to support teaching and learning and attainment of the desired science education outcomes." The NGSS performance expectations are the basis for assessments but are not assessments themselves. Assessment "tasks need to provide necessary evidence and should allow students to show what they know in ways that are as unambiguous as possible with respect to what the performance implies about student knowledge and skill."

Assessments that address the interlocking of core ideas with practices and crosscutting concepts like the NGSS do not presently exist, but the NAEP (administered to 4th, 8th, and 12th grade U.S. students) and PISA (administered internationally to 15-year olds) are both assessments that evaluate understanding of content combined with science practices. The exams for the new AP science curricula, which are designed by the principles of Wiggins and McTighe's *Understanding by Design*, likewise address science practice as well as science content.

In addition to the 20 challenges addressed by the authors of the seven reviews, *Science* editor Bruce Alberts in his editorial added three further challenges of his own. Robert E. Yager addresses them in a separate story on page 17.

Bruce Alberts, "Prioritizing Science Education" (p. 249)

21. "Build education systems that incorporate the advice of outstanding full-time classroom teachers when formulating education policy."

22. "Harness the influence of business organizations to strongly support the revolution in science education specified in the *Next Generation Science Standards,*"

23. "Incorporate active science inquiry into all introductory college science classes."

Bruce Alberts' Grand Challenges Offer Reforms Sought by Science Educators

By Robert E. Yager

Bruce Alberts grew up living near Chicago where his love of science started at an early age. He received a bachelor's degree in biochemical science and a doctorate in biophysics. Alberts is best known for having served as President of the National Academy of Science (NAS) for twelve years. He is an advocate of improving science education in both primary and secondary schools. It is apparent that his daughter's teaching has influenced Bruce as she continues teaching high school science in the San Francisco Public Schools.

Alberts also served for five years as Editor-in-Chief for the AAAS journal "*Science.*" As his service ended in 2013, he offered **Three Grand Challenges** for improving science teaching. The first Challenge was to encourage using the wisdom of teachers and education researchers alike. Specifically, it was to "*Build education systems that incorporate the advice of outstanding full-time classroom teachers when formulating education policies.*" Such teaching has been central to the National Science Teachers Association (NSTA) Exemplary Science Program (ESP) monographs.

The second Grand Challenge offered by Alberts was to "*Harness the influence of business organizations to strongly support the revolution in science education specific in the 2013 Next Generation Science Standards.*" He argued that we need more partnerships with business, industries, and education leaders across the world. Currently a major reform effort exists called STEM (Science, Technology, Engineering, and Mathematics) with innovations designed to prepare young people for future science careers. The NSTA publication "Exemplary STEM Programs: Designs for Success" illustrates how STEM reforms are being used to change science teaching at all levels (K-16).

The third Grand Challenge offered by Alberts was to *"Incorporate active science inquiry into all introductory college science classes."* Many college teachers are now accepting this challenge for improving college teaching. The STEM reform mandated exemplary science teaching should be approached without the typical use of textbooks, laboratory manuals, and teacher lectures. Such change is needed to exemplify evidence of real learning by students and not just their reciting what they remember from textbooks and lectures. Changing typical teaching methods used by college science faculty is one of the most needed changes (but *hardest* to achieve)! College professors often are only interested in research and grant funding – *not teaching!*

Alberts urges all, especially scientists, to be active collaborators and to focus on teaching that improves student learning and use of the information that illustrates the real "doing" of science. This means *exploring* the natural universe, seeking *explanations* of the objects and events encountered, and seeking **evidence** to support the explanations proposed. All teachers should encourage students to focus on "doing" science as opposed to just reciting what they remember from textbooks and teacher lectures. Current reforms of science can be met by using the three "Grand Challenges" offered by Bruce Alberts. But as Alberts stated in 2013, "A start has been made, but much more remains to be done."

(*Editor's Note*: Robert E. Yager is Professor of Science Education at the University of Iowa and Past President of the National Science Teachers Association and the National Association for Science, Technology, and Society. This has been republished with permission from NSTA, ©2015.)

STEM Teacher Leadership

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a teacher takes in being a teacher. But while beginning nurses follow a learning curve to develop the skills needed to do their job, professional development for teachers is rarely thought out along a learning curve. Although experience is seen as biased while research is seen as objective, she noted that both are important in guiding teachers. Among her conclusions: 1) Researchers need to learn how to do research that can get a handle on the mechanisms at play. (Example: Using what is known about approaching teacher evaluations to produce more learning from the evaluation.) 2) Systematically enhance teaching by making teacher learning more planned and deliberate. 3) Identify strategies to build leadership so teachers don't have to figure out how to lead on their own.

Just before lunch on 5 June 2014 Janet English, Teacher, El Toro High School (CA) and Member of the Organizing Committee, and Arthur Eisenkraft, Director of the Center Of Science and Mathematics In Context (COSMIC) at the University of Massachusetts, Boston, responded to the morning's plenary sessions. Eisenkraft cited research into the types of professional development teachers are seeking to enable them to teach revised AP science courses. Since teachers tend to work as equals rather than in hierarchies, he suggested that teacher leadership may be learning with other teachers rather than "I know what to do, let me help you." English said that she had learned the value of discussing what is working and what is not working while on a six-month Fulbright fel-

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STEM Teacher Leadership

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lowship in Finland. Given that "Everyone is a teacher leader in their own classroom," and that their classroom leadership results from their style, she knew she couldn't come back from Finland and just tell her fellow teachers what to do based on what she had learned there. But she knew she could have a conversation about what is working and what is not working.

The afternoon sessions on 5 June 2014 began with an "Overview of Additional Current Models of Engaging Teachers' Voices in Education Issues." Anthonette Peña of the Triangle Coalition for STEM Education presented information about the Albert Einstein Distinguished Educator Fellowships, funded by the John D. and Catherine T. MacArthur Foundation and managed by the US Department of Energy (USDOE) (which had delegated this responsibility to the Triangle Coalition until it recently took it over as an in-house function). Peña noted that four Fellows are placed in congressional offices, with the rest assigned to the National Science Foundation (NSF), USDOE, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration.

Nicole Gillespie described the Knowles Science Teaching Foundation Fellowships, established by the late Harry Knowles, founder of Metrologic, which provide five-year fellowships to support beginning high school STEM teachers to be "primary agents of change in the education system" and a senior fellowship as well. Fellows are supported to apply for National Board Certification and leadership grants. To Knowles, leadership must have an impact outside the classroom. More than 90% of the 500 Knowles Fellows thus far completed the program, and 80% are still K-12 teachers. The Foundation is now seeking a role for the network of teachers who have completed their fellowships.

Describing the program of Math for America was Marlena Jones, who said that it combines receiving a master's degree in math education with teaching math in DC secondary schools. A second smaller program supports five master teachers per year to become leaders in their schools and even outside their schools.

Nafeesa Owens next described the Presidential Awards for Excellence in Mathematics and Science Teaching. Directed by the NSF since its inception in 1983, "the highest recognition a math or science teacher can receive in the United States" is given to one math teacher and one science teacher in each state or jurisdiction every year. Owens stated that receiving this award makes a teacher a "certifiable leader" who finds doors open to connect with other leaders and to serve in a leadership capacity. The NSF is exploring ways to organize a program for "alumni."

Steven Long, Chair of the Teachers Advisory Council (TAC), under whose aegis the conference had been organized, reported that the Council had been established in 2002 by then National Academy of Sciences President Bruce Alberts to provide liaison between the science research and education communities. He added that the TAC works closely with Einstein fellows.

Lastly, Holly Emert described the Fulbright Distinguished Awards in Teaching Program, which is administered by the International Institute of Education in cooperation with the U.S. Department of State's Bureau of Educational and Cultural Affairs. Between 20 and 40 K-12 teachers every year are funded to go abroad between three and six months to take courses, visit schools, and complete a relevant capstone project. Teachers from some other countries also make reciprocal visits to the U.S.

The remainder of the afternoon of 5 June 2014 was spent in breakout sessions with the presenters and reports of "lessons learned" from these sessions, as summarized by facilitators.

The only additional plenary talk on 6 June came from Suzanne Donovan, who, like Suzanne Wilson, had also written one of the reviews in the 19 April 2013 issue of *Science*. Here she spoke on "Generating Continuous Improvement Cycles Through Research and Development." Solving educational challenges through merit pay and other economic incentives treats what happens in the classroom as a black box, but Donovan's poll of her audience suggested that they felt that only about a quarter of the problem could be solved in this way. Thus we need to open the black box to find out what it contains, Donovan said. This means bringing the results of research into the classroom. To this end, Donovan has worked to establish the Strategic Education Research Partnership (SERP), which she now heads. SERP's approach is to propose and test solutions, then make iterative revisions as needed, with teachers involved at every stage. Rather than give teachers extensive reading material to achieve desired reform of STEM education, they are given the desired principles of a STEM lesson on 5" x 8" cards that engage them as "an essential member of a team."

Further information can be obtained from a 78-page report written by Rapporteurs Steve Olson and Jay Labov, available online at <http://www.nap.edu/download.php?record_id=18984>.

Brahmia's synthesis

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Brahmia's synthesis of these practices into the four clusters of practices that embody what she feels is the essence of physicists' ways of thinking is as follows:

1. Reasoning mathematically with physical quantities:

CC1. Make sense of problems and persevere in solving them
CC2. Reason abstractly and quantitatively
CC5. Use appropriate (mathematical) tools strategically
AP2. Use mathematics appropriately
NG5. Using mathematics and computational thinking

2. Reasoning with mathematical models:

AP1. Use representations and models
AP6. Work with scientific explanations and theories
NG2. Developing and using models
NG7. Engaging in argument from evidence
CC3. Construct viable arguments and critique the reasoning of others
CC4. Model with mathematics

3. Reasoning based on mathematical structure:

AP7. Connect and relate knowledge across various scales, concepts, and representations in and across domains
CC7. Look for and make use of structure
CC8. Look for an express regularity in repeated reasoning

4. Experimentation as a way of creating knowledge:

NG1. Asking Questions and Defining Problems
AP3. Engage in scientific questioning to guide investigations
NG3. Planning and Carrying Out Investigations
AP4. Plan and implement data collection strategies
CC6. Attend to precision.
NG4. Analyzing and Interpreting Data
CC4. Model with mathematics.
AP5. Perform data analysis and evaluation of evidence
NG2. Developing and Using Models
CC3. Construct viable arguments and critique the reasoning of others.
NG6. Constructing Explanations and Designing Solutions

(*Editor's Note*: The foregoing is a more detailed report of Suzanne Brahmia's presentation to the March 2015 NJAAPT meeting than was presented in our Winter/Spring 2015 issue.)

Climate Change Update

(continued from page 3)

er their carbon imprint (in order to lower the cost of their energy). If China and the U.S. agreed to do this (and taxed goods from countries not doing it), he went on, we could obtain worldwide compliance. He lauded Citizens Climate Lobby for advocating this approach.

In the question-and-answer period following, I was able to ask Hansen the question I sought to address in the article I wrote on page 3 of the Winter/Spring 2015 issue of this *Newsletter*: "Does the difference in opinion about climate change result from the difference in values of climate sensitivity and, if so, why is there such a large range of values?" Hansen responded that his research group first got into determining climate sensitivity (the temperature increase from doubling the atmospheric concentration of carbon dioxide) in the 1970s with a climate change model and got 4^{o}C. Mnabe got 2^{o}C with his model, but Hansen had temperature-dependent cloud cover and Mnabe had fixed cloud cover. Another approach which Hansen cited is to compare our present interglacial conditions with those of the last ice age, when temperatures were 5^{o}C colder. This gives 3^{o}C per carbon dioxide concentration doubling, but it is no more accurate than values obtained from models (because there were no temperature measurements then, he said, only proxies). But Hansen felt that the 1^{o}C climate sensitivity value used by climate change deniers was definitely too low.

Geoscience Policies

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also runs award recognition programs for teachers, including the Edward C. Roy Award for Excellence in K – 8 Teaching. This award is presented each year in conjunction with the NESTA (National Earth Science Teachers Association) "Friends of Earth Science" Reception at the national NSTA Conference.

Even if you cannot participate in a CVD, you certainly should contact the District Offices of your Representative and Senators to let them know how you feel about issues. You can do this through their <http://www.house.gov/> and <http://www.senate.gov/> e-mails, if not in person. It's your Right as a Citizen!

After my visit to Washington, I was able to set up an appointment with the Project Specialist in the Newark Office of Senator Booker. Unlike the DC offices where visitors are fortunate to get 15 or 30 minutes before the staff members must greet a new set of "Messenger/Askers," the District Office staff often have more time and are available for one-on-one, in-depth discussions of issues.

Making Bridges from Discarded Materials

by Bernice Hauser
Primary Education Correspondent

I worked with a colleague who teaches developmentally challenged young children in a small nursery school — there are nine students in her class along with an assistant teacher – to develop an activity related to bridges using materials that would otherwise be discarded. We used hard cardboard rollers saved from Reynolds aluminum foil rollers (12½ by 1 inch cardboard rollers were the best of all those we tested), wooden blocks situated in the classroom, available clay, discarded newspapers, and other materials located in their classroom. Our main thrust was to create a viable bridge that four year olds could traverse on their own.

In our conversations together we realized how important it was for these students to work with concrete materials so that they can improve and enrich their language abilities and cognitive skills and learn to practice problem solving while also having opportunities to practice large and small motor skills and coordination exercises. (Although I no longer "do" science with young children, I enjoy mentoring and networking with teachers of young children on appropriate and viable methods and materials for infusing science into the classroom curriculum to enhance not only critical thinking processes but also decision making and problem solving experiences.)

We planned to use nine Reynolds cardboard rollers — one roller for each of the students to smell, sit on, push, roll, stand up, touch, feel, play with. The children were asked to do whatever they wished with their roller, on which was personally affixed some personal mark for easy identification. We sought to engage the children through their senses, seeing with their eyes, feeling with their hands. We had them play a version of hide and seek by locating objects in the classroom that are shaped like the roller — dowel sticks, straws, pencils, crayons, tin cans, and chalk that had all been placed around the classroom for them to locate. Together they experimented and discovered a common property of the shape of the roller. The teacher acted as a guide, posing questions to facilitate their responses and their discoveries as each child brought the object to her. Among the questions asked: If you blow on the straw, how far can it roll? What happens when you blow on the tin can? What do we have to do to make the tin can move? The goals of this activity were to have the children discover that all their objects are rounded objects and that they can roll on a surface — that they roll more easily on a non-carpeted surface than on a carpeted surface, that they roll faster on an inclined plane (analogous to a hill or a mountain slope) than on a flat surface. (An important component would be to retain and document these activities in a way compatible with the teachers' resources at hand and keeping in mind the students' ability to comprehend the concepts.)

The children were asked whether all the round objects they found would roll down the inclined plane or hill (large wooden block) at the same pace and whether they all roll the same distance away from the inclined plane. They were allowed to experiment, discuss their findings, and come up with their own scientific principles. These activities were to be spaced out because these children need constant reinforcement of what they had accomplished and what they had understood from previous lessons.

Students were also invited to compare the lengths of their rollers; they discovered that the rollers are of varying lengths. This led to comparison language games – *e.g.*, Alec is taller than the chair, Bobby is taller than the wastepaper basket, Jasmine is taller than her boot, Jill is shorter than the teacher, Ben is shorter than the bookcase – followed by a discussion of units and equipment to make measurements in science. Students were asked whether there is any object in the classroom we can use to determine a student's height? Students were asked to close their eyes and think back to the last time they visited their doctor. Did the doctor weigh them? Did the doctor measure their height — how was it done?

One child suggested that, once the position of his head and feet were marked, he cut a piece of string to match the distance between his head and feet. Then he would use his ruler to measure. The adults and children watched as he did this. He then positioned the string on the floor and placed his 12-inch ruler next to the string. "Oh, my string is much longer than my ruler," the child commented. The children eventually taped four rulers together and placed them next to the string and were able to calculate the child's height. Each child successfully completed this activity.

Several new items were introduced to the class – a yardstick, a flexible tape measure and a professional tape measure (a standard 10mts/33fts Power Tape/ Flexometro) used in commercial establishments. Conversations followed on how these measuring devices can save time and be used in different situations. Children chose one of these instruments to measure their height again with an adult's assistance.

Once the children had all these measuring devices in front of them, they were asked which one they would select or choose to measure how round your roller is? When you measure how round the roller is, you are measuring the circumference. Do the children choose the flexible tape or the string to measure the circumference of

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Discarded Materials

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their rollers? But if they choose another measuring instrument, they should be encouraged to discover if it works easily for them. A great follow up reinforcement is for them to measure their drinking cups – their lengths, their circumferences.

I think this is a good time to interject that in early childhood/nursery age classrooms the adults often encourage the children to converse, discuss and comment throughout their activities. The children are learning to negotiate to share materials, to voice their opinions, to hone their listening skills, and to disagree or agree in a reasonable discourse with each other. Any activity that stimulates these children also improves their motor skills is truly encouraged. This was alluded to in an article, "Occupational Therapy Increases Sharply Among the City's Students," by Elizabeth A. Harris, in *The New York Times* on Wednesday, 18 Feb 2015, which discussed the rising number of students who may need occupational therapy in order to cope successfully in mainstream classrooms. Having children manipulate and use materials successfully and to use their body parts correctly in the above mentioned classroom are implied goals of the classroom teachers.

For the next problem solving dilemma posed to the children, the adults turned to the classic children's story, *The Three Billy Goats Gruff*, written and illustrated by Paul Galdone. However, prior to introducing this beloved tale to the children, they had planned some walking tours to reinforce the concept of "what is a bridge?" Their first foray was across The Bank Rock Bridge, formerly the Oak Bridge, which leads to the Ramble, the "most intricately planted section of Central Park." They also crossed the rustic Shadow Bridge in the Ramble, a bridge that most resembles the bridge depicted in the *Three Billy Goats Gruff*. The edition of the book that the adults used — the 2001 Folk Tale Classic Series – shows a very basic simple old-fashioned wooden bridge constructed with logs.

On these excursions adults prepared sketchpads and colored crayons for each child to draw their impressions. Specific questions aimed to stimulate the children's cognitive, visual, and spatial acuity were posed to the children. Comparisons of the two bridges were encouraged as well as their sharing their personal experiences of going across the George Washington Bridge, the Koch Bridge and R.F. Kennedy Bridge to Queens, the Brooklyn Bridge, the Williamsburg Bridge, or the Manhattan Bridge with their families or friends. (New York City is especially blessed with an abundance of splendid, unique bridges to visit and to study.)

The following questions were asked of the students:

Before there were bridges, how did individuals get across the water to get to the other side?

Do you think automobiles are allowed to travel on this bridge? (Shadow Bridge)

What appears to be holding these bridges up?

What similar materials are used in the construction of these bridges—what different materials are used in the construction of these two bridges?

Which of these bridges are stronger? How did you decide?

Next the adults brought out many more Reynolds cardboard rollers for the culminating activity – namely, to create a model of a workable bridge using these cardboard rollers and other available materials. Working together and by using duck tape, Scotch tape, and tongue depressors taped to create sides and a railing, the children fashioned a prototype of a bridge – eight rollers for the bridge span, eight rollers for the foundation piles, eight rollers for the ends of the bridge span. Though an imperfect bridge model, the completed cardboard bridge elicited much discussion and stimulated and reinforced the next activity.

Next the adults distributed a copy of *The Three Billy Goats Gruff* to each child.

Depending on the technology available in the classroom, teachers can prepare a Power Point presentation of this tale from their computer onto the Smart Board in their classroom and read the story from this Smart Board. If a video is available, they may show it. Or they can read the story aloud to the children using the same text as the children have. This folk tale has myriad possibilities for creative and stimulating lesson plans and activities. However, the adults are basically utilizing this story to solve a dilemma — how will the goats get to the other side of the river to eat the green grass without being harmed by the troll?

Using blue tissue paper or construction paper, the children constructed a river in a corner of the classroom. Using green tissue paper or construction paper, they placed green grass on each side of the simulated river. Using available wooden blocks and the cardboard bridge as a prototype, the adults helped the children construct a viable mini-bridge in the classroom. (Many of the students suggested that the goats get a boat to get them across the river — certainly an acceptable solution that should be applauded and explored further – another stu-

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Discarded Materials

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dent suggested that "the goats can get into a plane and fly over the water.")

Referring to their excursion in Central Park and to the illustrations in their text, the children were encouraged to think about how they can construct their mini-bridge. Prodded by gentle suggestions and further questions, they decided to tie together with duck tape five or six wooden blocks which simulated wooden logs or planks.

Again the adults went back to the illustrations in the book and discussed possible options — they gave children some hints – the blocks in the classroom, the sand in the sandbox, the waste paper containers in the classroom, the saved newspapers in the classroom. The students decided to use all these materials – they also borrowed some waste paper containers from other classrooms. They filled the baskets or containers with all the small wooden blocks that they can hold.

They placed the bridge planks – wooden blocks – on top of these containers, and with twine and duct tape they firmly attached the bridge planks to the foundation supports (situated in these wastepaper containers). This bridge was constructed over the simulated river. An exciting moment then occurred in the classroom. A child cried out, "Look at how high the bridge is — if the goats are in the grass (the classroom grass) how will they climb onto the bridge to cross the river?" They were asked whether the goats could leap onto the bridge from the lower level of grass. Though the children agreed that the goats could leap from the pretend grass onto the constructed bridge, they decided to make mounds of grass (using newspapers) into hills leading right up to the bridge, to take blocks and pretend they were piles of stones that the goats could climb on to access the bridge (used as stepping stones), to use the stepstools in the classroom, and to take turns acting out the characters in *The Three Billy Goats Gruff.*

From the text they noticed that the goats needed no railings to go across the bridge but that they would feel safer holding onto a railing to get across the water. They used the yardsticks in the classroom as the railings and affixed them the best they could with twine and duct tape. One child volunteered to cross on the bridge, but he said he did not feel safe — the yardstick railings were neither sturdy nor secure enough to hold onto. This posed a vexing problem. The children examined pictures of the bridges from their story book and other photographs placed around the classroom. What could they use? The most viable solution that they came up with was to place three wooden chairs on each side against the bridge planks with the seats facing out; the slotted tops of the chairs provided the necessary sturdy railings for the children to feel secure walking across this bridge. After testing the simulated bridge several times, they also felt that it was better to have individuals go across the bridge in single file as it was not truly wide enough for two children side by side to cross over.

The children decided to invite their parents into the classroom for a reenactment of the story. Each of the nine children had a part in this presentation. But the story does not end here. The adults then planned a picnic excursion to Roosevelt Island. They took a bus over the Koch Queens Midtown Borough Bridge one way but used the Roosevelt Island Tram to come back.

Coming back to the school the adults requested that the school bus driver go north up Lexington Avenue. They asked the driver to stop at 68th St. and Lexington Ave. in New York City so that the students could view the Hunter College bridge that extends over Lexington Ave. (In a related discussion after this excursion the adults would pose this question: "Do bridges go only over bodies of water?")

Readers of this *Newsletter* know that I am a fierce advocate of teachers researching and reading up on everything concerning the topic/issue/subject that they will be teaching and experimenting and exploring with their charges in the school room. The subject of bridges happens to be one of my favorite subjects to explore with students in classrooms, no matter what age they happen to be. So do immerse yourself in the subject of bridges. You will be fascinated by what you both discover and learn.

Some Bridge Facts

- **Common types of bridges include beam bridges, arch bridges, suspension bridges, cantilever bridges, truss bridges and cable-stayed bridges.**
- **Bridge designs depend on their intended function, financial resources and also the type of terrain where they are constructed. While an arch bridge might be suited in one site, a suspension bridge might be suited in another.**
- **The Zhaozhou Bridge is the oldest standing bridge in China and the world's oldest stone segmental arch bridge. Built in 605AD, it is still standing strong today over 1400 years later.**
- **The Inca Civilization in South America made use of rope bridges in the Andes Mountains long before the European colonization in the 1500's. These rope bridges spanned canyons and valleys and gorges. While these bridges**

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were strong and reliable, repairing them was very difficult to do.

- **During the 19th Century Industrial Revolution, wrought iron was introduced to build bridges. It was later replaced by steel because it has a higher tensile strength.**
- **The first welded road bridge was designed by Polish engineer Stefan Brylaib in 1927.**
- **The Sydney Harbor Bridge in Australia can rise or fall up to 18 cm, depending on the temperature, due to the steel expanding or contracting. It also features six million rivets and weighs 39,006 tons.**
- **The Brooklyn Bridge in NYC joins Manhattan and Brooklyn over the East River. When completed in 1883 it was the longest suspension bridge in the world.**
- **The Golden Gate Bridge in San Francisco is a suspension bridge that was completed in 1937. It has a total length of 1280 meters (4199 feet).**
- **The longest suspension bridge in the world is the Akashi Kaikyo Bridge in Kobe, Japan. It opened in 1998 and spans 1991 meters (6532 feet).**

Resources and References

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www.exploratorium.edu/structures/newspapers.html: Wonderful resources for curricula on bridges and specific workable lesson plans to construct bridges out of various material.

http://Bridgepros.com/: This site is dedicated to the engineering, history and construction of bridges.

http://bridgepros.com/projects/index.html: This site features myriad bridge projects.

Super Bridge from PBSNOVA Online: http://www.pbs.org/wgbh/buildingbig/bridge/index.html

Lego Bridges: http://jacob.sparre.dk/LEGO/Transport/Broer/

ABCD's Bridge Design Tips for Kids: http://www.abcdpittsburgh.org/kids/kids.htm

West Point Bridge Designer: http://bridgecontest.usma.edu/download.htm At this site you can download a software tool developed to help you learn about engineering, computer-aided design and bridge structures. The software is in the public domain and intended for educational use only.

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News from Triangle Coalition

How NASA Broke the Gender Barrier in STEM

For the First Time, Half of the Astronaut Class is Women, and Now NASA is Offering New Opportunities for Female Tech Entrepreneurs

by Melissa Jun Rowley

The notorious lack of women in leadership roles in STEM seems to run rampant everywhere—everywhere except NASA, an administration that not only puts women at the helm, but continually gives them a platform to drive the larger conversation around the need for more women in the sciences.

Case in point: Dr. Ellen Stofan serves as the chief scientist of NASA. Deborah Diaz is NASA's chief technology officer for IT. Teresa Vanhooser runs one of NASA's largest facilities in the U.S. responsible for building rockets.

Dr. Tara Ruttley manages the science programs aboard the International Space Station. For the first time, half of an astronaut class consists of women. And now, through the convening of a new user community called Datanaut Corps, NASA is unlocking opportunities for women entrepreneurs in the tech and maker communities to use the agency's infinite gigabytes of open data to pioneer space-inspired data science.

The Datanauts program is emerging at an ideal time. As big as big data is, it needs diversity in order to thrive. According to a 2011 report by the Economics and Statistics Administration, women have seen zero employment growth in STEM jobs since 2000. Considering five of the top 10 jobs for millennials are of the tech and maker space, with "data scientist" coming in at No. 4, the need for the inclusion of women in STEM is more pressing than ever. The only way society will get closer to having a 360-degree perspective is through the democratization of roles across male-dominated industries.

"For women in science over the centuries, our contributions to so many fields are there, but they are not talked about as much as they should be," says Stofan. "So while most women in science have persevered by making significant contributions to every field, I think women in science today need to and are speaking up louder and louder to say, 'We are here, we are doing amazing science, and we are the role models for the next generation of STEM girls.'"

The convergence of open data and female leadership has the potential to challenge traditional decision making across sectors and facilitate more data-driven and collaborative approaches in creating new ventures and solving problems. Datanauts was born out of NASA's open-data priorities as a means to bring more women to the open-data table. While the program is intended for women and men, the founding class is made up entirely of women to encourage other female techies and makers to take the "data leap," as Beth Beck, Open Innovation program manager at NASA's Office of the Chief Information Officer, calls it. Future classes will include men.

"If you think about it, the small niche community of developers, mostly male, is the filter for NASA's open data as they develop tools to interpret NASA data according to their interests and priorities," says Beck. "Citizens consume what the developer community produces with our data. If the developer community had more women, I would imagine the tools created to interpret NASA's data would reflect different issues and priorities."

NASA's Datanaut Corps Founding Member Jennifer Lopez (no, not that one) is working to shape the direction of the Datanauts with NASA's Open Innovation team. She's hoping to inspire future engineers, scientists, entrepreneurs, and young people to learn more about data science and collaborate with NASA.

A Vision For Teacher Training At MIT: West Point Meets Bell Labs

by Claudio Sanchez

"Instead of focusing on courses and credits students need to take, we're going to focus on the skills and knowledge they need to have to enter the classroom," says Arthur Levine, the president of the Woodrow Wilson National Fellowship Foundation.

For decades, Arthur Levine, the former president of Teachers College, Columbia University, has tried to imagine a new kind of institution for training teachers. He envisions a combination West Point and Bell Labs, where researchers could study alongside future educators, learning what works and what's effective in the classroom. That idea is now set to become a reality.

This week, Levine and the Woodrow Wilson National Fellowship Foundation announced a $30 million partnership with the Massachusetts Institute of Technology with the goal of creating a better model for teacher training.

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Triangle Coalition

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Most education schools have such low admission standards and are of such poor quality, Levine says, it would be easier to replace them than repair them.

"They're old and dated," says Levine.

The new approach to teacher preparation will focus on what Levine calls "competencies," not seat time. MIT, which doesn't have a school of education, will conduct the research to guide the new curriculum and develop technologies focused on digital learning.

Levine says transparency will be a goal, and the lessons learned will be shared with education schools across the country.

"Our hope is that they'll take our ideas, take our practices and adopt them themselves," says Levine. Sharon Robinson, head of the American Association of Colleges for Teacher Education, says her group's 820 member institutions have always been wary of sweeping proposals, but this one is worth considering. "I will not be representing this as a threat to the membership of AACTE," Robinson says. In large part, she explains, because Levine's project is going to build on the innovation that's already going on in schools of education across the country. Besides, she says, Levine has a good track record of working with teachers' colleges, and that will go a long way in getting their collaboration.

Levine says the Woodrow Wilson Academy for Teaching and Learning will open its doors as a graduate school of education in June 2017.

Dow and Smithsonian Science Education Center Partner to Develop High Quality Teachers

by Sara Steele and Ashley Deese

The Dow Chemical Company (NYSE:DOW) and the Smithsonian Science Education Center announced today they will collaborate on The Dow Smithsonian Teacher Scholar Program. The program is designed to enhance teachers' skills related to STEM (science, technology, engineering and math) education by providing tools, resources and new learning experiences in fields such as earth history, biodiversity or energy.

The 6-day program will host 32 teachers in Washington, D.C. and is part of the Smithsonian Science Education Academies for Teachers (SSEATs). After the experience, participants will take their excitement and new skills back to the classroom, while receiving continued support from local peer participants and the Dow STEM Ambassador program. STEM Ambassadors support teachers and inspire students by providing real life examples to make challenging concepts easier to understand, while incorporating a strong focus on sharing exciting opportunities available through pursuing STEM careers.

(*Editor's Note*: The preceding three items were excerpted from the Triangle Coalition STEM Education Bulletin for 2 July 2015, reprinted with permission.)

LEAP Challenge calls for Signature Work

Because "a twenty-first-century education must prepare students to deal successfully with unscripted problems, . . . participate in an economy fueled by successful innovation and engage with diverse communities that urgently need solutions to intractable problems, . . . secure environmental sustainability, find ways to maintain human dignity and promote equity in an increasingly polarized nation, and manage a world rife with conflict," the Association of American Colleges and Universities (AAC&U) is marking its centennial by introducing the LEAP (Liberal Education and America's Promise) Challenge.

This Challenge is "to make Signature Work a goal for all students and the expected standard of quality learning in college." In doing Signature Work, "a student uses his or her cumulative learning to pursue a significant project related to a problem he or she defines." "Through Signature Work, students immerse themselves in exploration, choosing the questions they want to study and preparing to explain the significance of their work to others. This process helps students develop the capacities . . . required to grapple with problems where the 'right answer' is still unknown and where any answer may be actively contested." It can help students "get more out of higher education and prepare more effectively for work and life. It helps students integrate their major area of study with other disciplines and apply what they have learned to real-world situations."

The LEAP Essential Learning Outcomes from doing Signature Work are 1) "Knowledge of Human Cultures and the Physical and Natural World," 2) "Intellectual and Practical Skills, including inquiry and analysis, critical and creative thinking, written and oral communication, quantitative literacy, information literacy, [and] teamwork and problem solving," 3) "Personal and Social Responsibility," and 4) "Integrative and Applied Learning."

(*Editor's Note*: The foregoing is adapted from <http://www.aacu.org/libereducationon/2015/winter-spring/the-leap-challenge?utm_medium=email&utm_source=lewisp158&utm_campaign+lewisp15>.)

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Vivien Marx, "Sharp Shooters," *Nature*, **508**, 133-138 (3 Apr 14).

Proton beams are more effective at targeting tumors than x-rays, which are also more likely to kill adjacent healthy tissue, and ions of heavier elements, principally carbon, are even more effective than protons. This article describes research not only with carbon ion treatment but also with efforts to reduce the size and cost of equipment, largely from building smaller, more powerful magnets.

(*Editor's Note*: Cancer treatment with proton beams has been previously covered in the Winter/Spring issues of this *Newsletter* for both 2009 and 2011.)

2. David Wolman, "The Aftershocks," <https://medium.com/matter/the-aftershocks-7966d0cdec66>.

This article is a detailed telling of the story of the conviction of seven Italian scientists of involuntary manslaughter for "inexact, incomplete, and contradictory information" before the 5.8-earthquake which struck L'Aquila, Italy, on 5 April 2009. This story is followed by a discussion of different perception of abstract words used to describe probabilities, especially for events which rarely occur, and human failure to lose track of how small probabilities can achieve significance over a sufficient period of time. The author also suggests advice to the scientists in their appeal of the judge's decision.

(*Editor's Note*: This story was the basis for the "Infusion Tip" in the Fall 2013 issue of this *Newsletter*.)

3. Mason Inman, "The Fracking Fallacy," *Nature*, **516**, 28-30 (4 Dec 14).

Although the U.S. Energy Information Administration was initially surprised by the increased domestic production of natural gas from hydraulic fracturing (fracking), its present forecast of future production is regarded as unrealistically high by a group of academicians at institutions of higher learning in Texas.

4. M. Mitchell Waldrop, "The Fusion Upstarts," *Nature*, **511**, 398-400 (24 July 14).

While the lion's share of governmental funding for energy from nuclear fusion is going to the ITER tokamak to heat a magnetically-confined deuterium-tritium plasma, despite cost overruns and delays, independent entrepreneurs are seeking alternative methods of releasing energy from nuclear fusion, including the fusion of protons with nuclei of boron-11.

5. Gabriel Kahn, "Bonanza," *Pacific Standard*, **8**(4), 34-45 (Jul/Aug 15).

Converting a 500 square mile ranch in Wyoming (where some of America's heftiest winds blow) into a gigantic wind farm could provide all the electric energy needed by Los Angeles and San Francisco, but there are political and scientific hurdles to overcome: assuring the safety of sage grouse (if declared endangered, would cripple the state's coal industry, source of its economic livelihood) and eagles, and obtaining rights-of-way to build a transmission line to California. Though the plan was originally conceived in 2006, there is yet no evidence of executing it. Meanwhile, Californians have been putting up their own wind turbines and decking their roofs with solar panels to the point of providing 25 percent of their electrical energy renewably, close to the 33 percent figure former Governor Schwarzenegger had mandated by 2020. On the other hand, present Governor Brown's pledge "to cut California's greenhouse gas emissions to 40 percent below 1990 levels by 2030" could still make the project economically viable.

6. Gregory J. Gbur, "A Protective Cloak Against Earthquakes and Storms," *Am. Sci.*, **103**(5). 356-359 (Sep-Oct 15).

Things are made visible by the light waves reflecting from them into our eyes. If light rays could be made to go around an object rather than be reflected by it, the object would be invisible. While this is difficult for light waves because of the small wavelength of visible light and the limit imposed on the speed of light by the special theory of relativity, it is being considered as a way of "cloaking" objects so that they are not impinged by other waves – *e.g.*, seismic waves from earthquakes and ocean waves from violent storms.

7. Anne R. Douglass, Paul A. Newman, and Susan Solomon, "The Antarctic Ozone Hole: An Update," *Phys. Today*, **67**(7), 42-48 (Jul 14).

Only after chlorofluorocarbons rise above the ozone layer can solar ultraviolet radiation, which is absorbed by ozone, break them down and free chlorine atoms, which in turn destroy the ozone. The persistence of the effects of chlorofluorocarbons results from their persistence in the atmosphere: only about 1% of the air in the atmosphere rises high enough each year for its chlorofluorocarbons to experience significant breakdown. The ozone-destroying capability of bromine is sixty times that of chlorine.

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Chlorine concentration in the upper stratosphere peaked at about seven times the 0.5 ppbv (parts per billion by volume) from naturally-occurring methyl chloride in 1998 but has retreated since – now back to the level of 1995. The size of the ozone hole is found to depend more on the temperature of the stratosphere than its chlorine concentration. Higher temperatures bring smaller ozone holes, and high temperatures in the Northern Hemisphere contribute to smaller ozone holes there. Models predict that Antarctic ozone levels will return to their 1980 values between 2050 and 2070.

8. J. Michael Pearson, "On the belated discovery of fission," *Phys. Today*, **68** (6), 40-45 (Jun 15).

Enrico Fermi was the first to bombard uranium with neutrons (in 1934) but did not discover nuclear fission, and announcement of the discovery by Otto Hahn and Fritz Strassmann four years later was accompanied by a statement of skepticism, because until that time no one (except for chemist Ida Noddack) thought that anything larger than an alpha particle could be emitted from a nucleus in a nuclear reaction, and Fermi had taken steps to exclude that. (Noddack published an objection that Fermi had not excluded the breakup of the bombarded uranium into two or more nuclei of comparable size in the same year Fermi published his work, but she did so in a chemical journal not known to many physicists, and Fermi did not respond to her objection.) Nor did Irène Joliot-Curie and Pavel Savić discover fission when after bombarding uranium with neutrons five months before Hahn and Strassman they ascribed beta activity associated with lanthanum to its actinide homologue.

Yet all the ideas needed to interpret the results in terms of nuclear fission were available before its discovery was announced: Niels Bohr's model of a compound nucleus resulting from such bombardment had been proposed in 1936, as an extension of George Gamow's model of the nucleus as a liquid drop in 1930. And the semi-empirical nuclear mass formula developed in 1936 showed that if a uranium nucleus were split into two approximately equal nuclei, a lot of energy and free neutrons would be released. All these ideas were subsequently applied by Lise Meitner (who had worked with Hahn and Strassmann but was now a Jewish refugee in Sweden) and her nephew Otto Frisch (who worked with Bohr) to understand how the uranium nuclei had fissioned after neutron bombardment: after the compound nucleus (of uranium plus one additional neutron) formed, the additional energy brought by the additional neutron caused it to vibrate and split. The final details of the fission process would shortly be worked out by Bohr and John Wheeler after Bohr hand-carried Meitner and Frisch's paper on an already-planned visit to the United States.

Although the ideas used by Meitner and Frisch were not available when Fermi did his work in 1934, they *were* available in 1936, two years before Hahn and Strassmann announced their discovery, and Pearson speculates on how this might have altered the course of world history: "The war almost would have taken a different form had fission been discovered even two years earlier. Quite possibly it would have gone nuclear earlier, although the fear of nuclear weapons could conceivably have prevented war altogether – and, as a side effect, allowed the Nazi regime to survive. On the other hand, that same fear might well have accelerated the outbreak of war, with each side seeking to destroy the other's nuclear installations with conventional arms."

9. Elizabeth Schibuk, "Teaching the Manhattan Project," *Sci. Teach.*, **82**(7), 27-33 (Oct 15).

Although this author teaches the subject as a unit of nuclear chemistry, it can also be taught as a unit of nuclear physics. She shows how the subject combines meeting the Next Generation Science Standards with fostering "students' understanding of the relationship between democratic citizenship and school science." The list of references, which include the film *Day One* and the graphic novel *Trinity*, is invaluable.

10. Spencer Weart, "Climate change impacts: the growth of understanding," *Phys. Today*, **68**(9), 46-52 (Sep 15).

Except for primary work by the likes of Svante Arrhenius and Roger Revelle, the recipient of the American Physical Society's 2015 Abraham Pais Prize for History of Physics observes that the major players in the development of the understanding of climate change and its impacts were panels and committees rather than individuals. Their work began in the 1960s with largely seat-of-the-pants guesses characterized by a lot of quantitative uncertainty, which was often the basis of consensus reached by the group. Two decades later, though, the development of general circulation models of the atmosphere allowed for more specific predictions, which agreed with the earlier guesses globally but made divergent predictions for specific individual regions.

11. Carey W. King, "The Rising Cost of Resources and Global Indicators of Change," *Am. Sci.*, **103**(6), 410-417 (Nov-Dec 15).

If cost is defined by percentage of GDP, the cost of food and energy declined for 70 years before hitting a minimum in 2002 in the U.S. and for 30 years before hitting a minimum in 2000 in the world. Several driving factors suggest that this minimum will never again be reached, among them population and the increased percentage that is non-working, aging energy infrastructure, and increased energy cost of energy.

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Greg Craven, *What's the Worst That Could Happen? A Rational Response to the Climate Change Debate* (Penguin, New York, 2009) 264 pp. $14.95. ISBN 978-0-399-53501-7.

I asked to review this book because I was curious to see what a fellow high school physics and chemistry teacher had to offer on the subject of climate change which has captured my interest and concern ever since I worked with NSTA in the summer of 1979 to develop a curriculum about it. I was not disappointed. I was greeted by eleven engagingly written chapters presenting no "graphs and footnotes to convince you which side is right" but rather "a set of thinking tools so you can reach *your own* conclusion." (p. 4)

Craven's approach follows from his philosophy that "the real question about dangerous global warming is not, Is it true? But, Is it worth doing anything about, just in case it's true?" (p. 11) To him the issue of climate change is one of security for the future threatened by climate destabilization. Thus, he chooses to think of it in terms of risk management, and he spends his first chapter (numbered zero and titled "Should I bother to read this book?") making sure that his readers are "on board" with him. The key, he points out in that introductory chapter, is a decision grid, with two columns – A ("significant action now") and B ("little to no action now") – and two rows – whether global warming is false or true. We aren't sure about the rows, he says, though we can estimate their probabilities, but we do have control of the columns.

Before reading Chapter 1, Craven's readers are asked to write what they would have to see for their opinion about global warming to be changed. (If you can't answer this, he says, your mind can't be changed so there's no point in reading the book.) This and the next four chapters are devoted to developing a "tool kit" (spelled out on pages 104-105) to facilitate completing the decision grid in the last half of the book. Among the tools are the realization that there cannot be a complete consensus about something scientific, though it can be well accepted or established, and strategies for avoiding "confirmation bias" (looking for supportive but not opposing evidence – it "tricks you into being wrong *with confidence*" (p. 65)). To guard against confirmation bias in filling out our decision grid, we also need to develop a "credibility spectrum" – a chart for each side of the issue, with spaces along a line from "most credible" to "least credible" for information from various types of sources.

In Chapter 6 Craven presents the information he has gathered from the "warmers," his name for those who believe the climate is warming and in taking action to oppose it. In Chapter 7 he does the same for the "skeptics." But because he feels that "the shrill urgency of the warmers . . . in Chapter 6 defies common sense (p. 149)," Craven also devotes Chapter 8 to exploring their arguments. Here he points out that "It's not the temperature rise that gets you but what it causes." (p. 157) More than climate *change*, warmers are concerned about climate *destabilization*, characterized by rising sea levels and attendant increased storm surges, increased range of pests and disease-spreading insects and agricultural losses and illness, changing rainfall patterns, more frequent and extreme weather events, collapse of the "conveyor belt" that keeps Northern Europe warm, and changing relationships among species.

Craven likens the global atmosphere to financial markets: both, he says, are complex dynamical systems, with many connected elements and feedback loops, which can lead to erratic behavior – *i.e.*, destabilization. Financial markets represent an experiment with our economic system, the atmosphere an experiment with our planet. Among the factors affecting feedback loops are phytoplankton, trees, the Earth's albedo, methane hydrates, the aforementioned "conveyor," ice sheets, and peat. Climate destabilization would be characterized by a "tipping point," marking a change beyond which there could be no return. Craven notes the difficulty identifying tipping points due to 1) omission of positive feedback loops in climate models (because we don't understand them sufficiently) and 2) the abruptness of climate change in the past, evidence for which has been found only since the 1990s and which is the focus of the National Research Council report, *Abrupt Climate Change*, issued in 2002. Before that, a 20^{o}F temperature difference over a period of 10,000 years was believed to have occurred at a constant rate over the entire time, but it is now known to have occurred in a 100-year period during those 10,000 years.

Craven uses the imagery of *Abrupt Climate Change*, which depicts the transition of a mechanical system from one equilibrium state to another, to represent two climate states – glacial and interglacial – between which the Earth has flipped over the past three million years, with changes between these climate states occurring over short periods of 100 years. The transition between equilibrium states is expressed as two energy wells separated by a hill. The rapidity of climate change in the past causes Craven to wonder how much human action has gone to push our present climate system up a "hill" on the other side of which is another climate system from which we

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can't return and whether stabilizing our climate at an elevated average global temperature by controlling carbon emissions at present values could put us at greater risk. It also leaves him with the feeling that the IPCC model predictions are rendered even more conservative, because they don't predict such rapid climate change in the past.

When, in Chapter 9, Craven assembles his credibility spectra for taking and not taking action on climate change, he finds that the spectrum for not taking action is lean for the most credible types of sources – statements from professional societies and statements from organizations that contradict their normal bias. This, coupled with the strong statements for taking action from three different communities – science, business, and national security – leads him to consider that global warming is far more probably true than false, and he chooses column A on his decision grid. Chapter 10 invites readers to complete their own decision grids.

James Hansen, characterized as an accepted bellwether, is cited as saying that avoiding a climate tipping point requires ending coal combustion by 2030. According to Craven, "that means we need to be on a very different track by 2015" (p. 216), unless we can bring about cultural change at the rate we geared up for World War II. Craven concedes that, unlike Hitler and Hirohito, carbon dioxide emissions are an enemy without a face to motivate us, but he feels that today's milieu of digital communications could allow a "viral spread of the meme that we should change the question in the global warming debate from, Is it true? to, Why risk it?" (p. 222) Thus he passes the torch to achieve this to his readers. But it is now 2015, and the carbon dioxide concentration in the atmosphere is up to 400 parts per million from the 388 when Craven wrote his book. We have burned less coal, but only because we have replaced it with "fracked" natural gas, and we have increased production of another fossil fuel, oil, from tar sands and oil shale. Although more than a million saw Craven's YouTube video ("The Most Terrifying Video You'll Ever See") in less than a year, are we any more culturally mobilized to oppose climate change?

\- John L. Roeder

(*Editor's Note*: The preceding review was originally written for the American Physical Society's publication, "Physics and Society." As I was writing it, I fortuitously encountered a column about Pope Francis's encyclical in the 22 June 2015 issue of *The Times* of Trenton by Leonard Pitts, Jr., of *The Miami Herald*, which essentially completed Craven's decision grid the same way he did: "It seems to me we are dealing with competing worst-case scenarios. One, pushed by the political right, holds that the imposition of restrictions and regulations to arrest climate change would cripple businesses with needless expenses. . . . That's not a great outcome, granted. But consider the other worst-case scenario: We do nothing. It turns out the overwhelming consensus of the scientific community was right and we are left scrambling for dwindling resources on a dying planet.

In other words, one 'worst-case scenario,' we survive, albeit economically weakened. The other, we do not survive at all. . . . We are asked, in effect, to decide between future regrets: One: We could have saved some money and didn't. Two: We could have saved the planet – and failed.")

Marcia Batusiak, *Black Hole* (Yale, New Haven, 2015). 237 pp. $12.99 (Kindle), $17.68 (hardcover). ISBN 978-0-300-21085-9.

In 1992, the Lemon Bay High School Astronomy Club in Englewood, Florida, opened an observatory. The main telescope was a ten inch reflector that had been donated by an amateur astronomer in the community. The club operated four other good telescopes which had also been donated.

Beginning that year, twice each month from early October through mid-April, the observatory was opened to the school community and the public. It was also opened when special observing opportunities occurred, such as lunar and solar eclipses.

On regularly scheduled viewing nights, I often found that students were happy to use the telescopes but intent on asking questions and talking about astronomy, in particular, about black holes. I would have liked to have had a few copies of this book by Marcia Batusiak in our school library to recommend to them.

The book is well written and thoroughly researched. This reviewer learned several interesting things while reading it, including the work of John Michell. Batusiak notes that "Science historian Russell McCormmach has written that Michell was the most inventive of the eighteenth-century natural philosophers." In a paper read to the Royal Society in December 1783 and January 1784, Michell describes how a black hole, which he identifies as an invisible star, might form.

Batusiak does an excellent job summarizing the work of Albert Einstein on general relativity, and includes information about Karl Schwarzchild's full solution to the equations that represent the theory. This led to the recognition of the "Schwarzchild radius," which is now recognized as the event horizon of a black hole.

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Quantum mechanics was needed to describe the process by which a black hole forms, and Batusiak describes the process. This includes details of the work of Subramanian Chandrasekhar, including his dilemma with astronomer Arthur Eddington. Bartusiak writes of the state of the theory of general relativity, until it was applied to black hole physics, as being a "playtoy for mathematical physicists." She quotes Richard Feynman speaking about the theory; "Few of the best men are doing work in it. The good men are occupied elsewhere." Bartusiak indicates that things had gotten so bad that in the 1950s Samuel Goudsmit, editor-in-chief of *Physical Review*, was about to stop accepting papers on general relativity.

Then, Roger Babson, an engineer who had applied his skills to stock market analysis and became very rich, established the Gravity Research Foundation. Two activities the foundation supported were establishing awards for the best essays written on gravity, and support of conferences with gravity as the central topic.

Batusiak also describes the work of John Wheeler as being a key to establishing general relativity as an active research topic in the United States. Wheeler is a central figure in *Black Hole*. Batusiak writes of the importance of the discovery of quasars. She describes the initial meeting of the Texas Symposium on Relativistic Astrophysics in 1963 and the fact that at the symposium "physicists first learned that relativity might actually be significant in the physical world."

The work of Roy Kerr is described, including his discovery, in 1962, of black hole angular momentum, and the resulting frame dragging that occurs. Frame dragging is a relativistic effect predicted by Josef Lense and Hans Thirring in 1918. Kerr's work confirmed the prediction. Batusiak's description of the excitement caused by Kerr's work is enjoyable to read.

Batusiak presents information about the importance of the development of X-ray astronomy in black hole research, including the discovery of the first X-ray source in space, Sco X-1. The concluding chapter, titled "Black Holes Ain't So Black," deals with the work of Stephen Hawking, in particular the nature of the event horizon of a black hole.

Batusiak is a professor in the Graduate Program in Science Writing at MIT. In writing *Black Hole*, she has provided an excellent resource for those interested in the process of science in general, and black hole physics in particular.

\- Frank Lock

(*Editor's Note*: Frank Lock, now retired from Lemon Bay High School and presently Teacher In Residence in the Physics and Astronomy Department, Georgia State University, is a frequent book reviewer for the *Newsletter*).

Michio Kaku, *The Future of the Mind: The Scientific Quest to Understand, Enhance, and Empower the Mind* (Doubleday, New York, 2014). xviii + 377 pp. ISBN 978-0-385-53082-8.

I decided to read this book because I have always wanted to know more about how the mind and consciousness are related to the working of the brain. Kaku in his introduction informed me that I would be in for much more than this. Could the chips already implanted in the brains of paralyzed people so they can mentally manipulate computers connected to the chips be connected to exoskeletons to give quadriplegics near normal lives or allow astronauts on Earth to control mechanical surrogates on distant planets? Can memories like those which have been inserted into animals be inserted in humans as a way to teach new skills? Could we transmit ideas and emotions electronically? Once we decipher the neural circuitry of the brain, could we copy the brain and upload our consciousness to a computer, where it could live forever?

In his book, Kaku explains how the answer to all these questions could be "yes," although he doesn't compare the time to insert memory with that required for actual learning, but first he needs to set the scene by discussing mind and consciousness, which he does in the first two of his fifteen chapters. He discusses brain structure in the first chapter and consciousness in the second in terms of three evolutionary stages. First there is what is called the "reptilian brain," consisting of the brain stem, cerebellum, and basal ganglia, which governs animal functions and behavior needed for survival and reproduction. Second comes what is called the "mammalian brain," in which to the reptilian brain is added the limbic system, which enables mammals to live in social groups – the hippocampus (transforming short-term memories into long-term memories), the amygdala (registering and generating emotions), the thalamus (relaying sensory signals from the brain stem to the appropriate cortex, and the hypothalamus (regulating body temperature, circadian rhythm, hunger and thirst, and sexual pleasure) – and the "most recent region of the mammalian brain, the cerebral cortex, which is the outer layer of the brain." (p. 20) "The latest evolutionary structure within the cerebral cortex is the neocortex . . . , which governs higher cognitive behavior. It is most highly developed in humans: it makes up 80 percent of our brain's mass, yet is only as thick as a napkin." (p. 20) [Jeff Hawkins regarded the neocortex as the key to human intelligence in the book he

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wrote with Sandra Blakeslee, *On Intelligence*, reviewed in our Winter/Spring 2009 issue.]

Kaku lists and describes the means by which neuroscientists have investigated the operation of the brain and notes particularly that MRIs have shown that thinking is not concentrated in a single center, thus discounting the switchboard or computer as a model for the brain. Rather, Kaku finds a corporation to be a helpful analogy, characterized by a bureaucracy whose several elements are connected to the CEO by lines of authority. The competition of components of the bureaucracy for attention of the CEO reflects what is seen in brain scans. The CEO, "located in the prefrontal cortex" (p. 35), has to make final decisions requiring the type of reasoning which is done there, but most decisions, including reactions to emergencies, are handled at a lower level – the CEO does not want to suffer from information overload. In fact, the brain has only 20 watts of power to do its work – more would make the body dysfunctional and cause tissue damage.

Kaku's definition of consciousness is "the process of creating a model of the world using multiple feedback loops in various parameters . . . in order to accomplish a goal." (p. 43) "Human consciousness is a specific form of consciousness that creates a model of the world and then simulates it in time, by evaluating many feedback loops in order to make a decision to achieve a goal," he later adds. (p. 46) Human consciousness, with its unique sensitivity to time, is the highest level of consciousness, corresponding to the capabilities of the human brain, which Kaku characterizes as Level III, with Level I consciousness characterizing organisms with a reptilian brain, which are mobile and have a sense of space, and Level II characterizing organisms with a mammalian brain, which additionally have a sense of social relationships.

Kaku elaborates on the unique human sensitivity to time by observing that there is no evidence that animals share the human trait of planning for the future. He proposes the dorsolateral prefrontal cortex (area 10, the internal granular layer IV, in the lateral prefrontal cortex), which "is almost twice as large in humans as in apes," as "a candidate for the precise area of the brain where simulation of the future takes place." (p. 46) Being able to plan for the future gives humans an edge over other species, and the "CEO" which does this is more successful in making decisions than the instinctual actions of animals. Kaku's definition of self-awareness is similar to that of consciousness: "creating a model of the world and simulating the future in which you appear." (p. 57) Both definitions involve "creating a model" – something the human brain allows us to do for ourselves. Although "consciousness is cobbled together from many subunits of the brain," Kaku goes on, "each competing with the others to create a model of the world, . . . yet our consciousness feels smooth and continuous." (p. 58)

The remainder of Kaku's book is largely a series of applications of what has been set forth in the first two chapters. Within the context of these two chapters, succeeding chapters discuss what has been learned from modern neuroscience and what might be expected in the future related to such phenomena as telepathy, telekinesis, memory, intelligence enhancement, dreams, external control of the mind, mental disorders, robotics, the structure of the brain, immortality, electromagnetic transmission of a brain's contents, and aliens. Two anecdotal items in the chapter on intelligence enhancement which I found particularly fascinating are 1) a 1972-1988 longitudinal study by Walter Mischel that found the ability to delay gratification to be a more reliable indicator of success in life than an IQ test and 2) the 1.5% genetic difference between humans and chimpanzees which accounts for our greater lifetime and intellectual skills: 118 base pairs that had mutated from chimpanzee genes – in the regions HAR1 (important "controlling the overall layout of the cerebral cortex"), FOX2 ("crucial for the development of speech"), HAR2 (giving our fingers added dexterity), and ASPM ("thought to be responsible for the explosive growth of our brain capacity"), discovered by Katherine Pollard (pp. 153-154) – and the RIM-941 gene, isolated in November 2012 by a team at the University of Edinburgh, "which is the only gene ever discovered that is found strictly in *Homo sapiens* and not in other primates." (p. 155)

Because Kaku is a professor of theoretical physics, he recognized the need to benefit from the expertise of experts in other fields to write this book, and he did so. He acknowledges such benefit from approximately 200 such experts, the list of which occupies more than six pages. Yet the book clearly bears his own personal touch and genuine interest in his subject. To those concerned about threats to the human future from robots, nanobots, and bioengineered agents, he feels that only the last is immediate and that adequate safeguards can be established. Though Kaku has acknowledged the possible use of technology for good or ill throughout his book, he points to the historical record as favoring its use for good (though making present-day life too "soft" has not necessarily been good for our health). He draws his discussion to a close in terms of the Copernican Principle – that "there is no privileged position for humanity" (p. 323) – and the Anthropic Principle – "that the universe is compatible with life" (p. 324). Though the Copernican Principle would reduce "our thoughts, desires, hopes, and aspirations . . . to electrical impulses circulating in some region of the prefrontal cortex" (p. 325), the Anthropic Principle "says that conditions of the universe make consciousness

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possible." (p. 325) "We should treasure the consciousness that is found on Earth," he writes. "The highest form of complexity known in the universe, and probably also the rarest" is "something that sits on our shoulders." (p. 327)

\- John L. Roeder

Naomi Oreskes & Erik M. Conway. *The Collapse of Western Civilization: A View from the Future* (Columbia University Press, New York, 2014). 104 pp. $9.95. ISBN 978-0-231-16954-7.

The increasing concentration of CO_2 in the atmosphere, a primary cause of global warming, has moved from under 320 ppm since Charles David Keeling began measuring it in the late 1950s at Hawaii's Mauna Loa observatory to about 400 ppm at present. Decade over decade the *rate* of increase has grown. At the same time, scientists' understanding of the dynamics of climate change, including humanity's central role in generating excess CO_2, has increased greatly, and decades of warnings to policymakers (from five IPCC reports and other sources) have grown ever more alarming.

In this sobering context Naomi Oreskes and Erik Conway published a short book last year called *The Collapse of Western Civilization: A View from the Future*. Their fictional narrative, ostensibly written centuries from now, reflects on why civilization was unable to come to grips with climate change despite a robust scientific understanding of the problem.

The book's flyleaf reads, "*The year is 2393 and the world is almost unrecognizable. Clear warnings of climate catastrophe went ignored for decades, leading to soaring temperatures, rising sea levels, widespread drought and – finally – the disaster now known as the Great Collapse in 2093, when the disintegration of the West Antarctica Ice Sheet led to mass migration and a complete reshuffling of the global order. Writing from the Second People's Republic of China on the 300th anniversary of the Great Collapse, a senior scholar presents a gripping and deeply disturbing account of how the children of the Enlightenment – the political and economic elites of the so-called advanced industrial societies – failed to act, and so brought about the collapse of Western civilization.*"

Why would Oreskes and Conway, respected scholars, turn to writing fiction, albeit science-based fiction? In part, they knew that their earlier writings, and those of hundreds of scientists, had not yet persuaded policymakers and the public of the urgent need for action. They thought that fiction might be a more effective communication vehicle than writing additional scientific books, articles, and reports.

Fiction also offers opportunities to speculate more freely than research. Looking back from the future, what do Oreskes and Conway suppose *were* the major stumbling blocks preventing effective action on climate change? What *were* the catastrophic results of delay, and on what time scale did those results unfold? *The Collapse of Western Civilization* offers answers.

Naturally, multiple answers are provided; however, the central reason described by Oreskes and Conway why civilization failed to respond quickly enough to climate change is that so many policymakers have an ideological fixation on – almost a religious faith in – so-called free markets. That blind fixation can be illustrated by Alan Greenspan's admission in 2008, after the recession rocked world finances, that he had put too much faith in the self-correcting nature of free markets. "*Those of us who have looked to the self-interest of lending institutions to protect shareholders' equity, myself included, are in a state of shocked disbelief*," he told the House Committee on Oversight and Government Reform. It was and is shocking, indeed, that Greenspan or anyone else could have believed that extreme "market fundamentalism" is always self-correcting and a good thing.

Unfortunately, most conservative politicians in the U.S. and elsewhere still believe all or nearly all regulations and taxes stifle economic growth *and* personal freedom and must be resisted. This ideological bias causes many conservatives to deny that human beings are the major causes of climate change, as is documented in an earlier book by Oreskes & Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. Too often the public shares this attitude; for example, increasing gasoline taxes to fight climate change would almost certainly be highly unpopular despite the fact that a carbon tax would harness competition—a mechanism central to capitalism and dear to conservatives—to reduce greenhouse gas emissions.

In addition, *The Collapse of Western Civilization* says that the arbitrary selection by scientists of a 95% confidence level as the appropriate threshold for judging virtually all research as accurate has been a significant barrier to combating climate change. Many scientists, according to the book's fictional narrator, waited far too long before publicly declaring that humans were causing catastrophic changes in the climate.

Other aspects of psychology are also explanatory factors identified in the book, which points, for example, to "human adaptive optimism" as a reason why civilization delayed any meaningful response. Nonetheless, I believe the authors might productively have focused even greater attention in the book on the many ways human psychology acts as a barrier to combating climate change. One

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scholarly article, *The dragons of inaction* by Robert Gifford, identifies 29 different reasons why human beings resist acting on climate change.

Like *Merchants of Doubt* before it (recently made into a movie), *The Collapse of Western Civilization* is carefully researched and well written, and presents information that will be new to many readers. For example, I had not known that by 2012 more than half of all anthropogenic greenhouse gases were emitted *after* the mid-1970s; "that is," the book's narrator writes, "*after* scientists had built computer models demonstrating that greenhouse gases would cause warming" (p. 18).

Dystopias like *The Collapse of Western Civilization* are intentionally disturbing yet they have their place; consider George Orwell's long-lived, influential novel *1984* But in imagining a positive impact for dystopian books one must assume that they are widely read and stimulate influential readers to think and act more thoughtfully. Time will tell if that happens with this thoughtful, stimulating book.

\- Andy Zucker

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

Charles R. Morris, *The Dawn of Innovation: The First American Industrial Revolution* (Public Affairs, 2012). $28.99. 384 pp. ISBN 978-1-58648-828-4.

We often attribute the spark of America's economic engines to the second half of the 20th century. Prodigious inventions and discoveries resulted from the post–World War II economic boon and fears of second-class world status in technology after the Soviet Union's successful Sputnik launch. We are still benefiting from the innovation which poured from the corporate research laboratories of America's blue-chip companies and the fast-growing populations of America's research universities.

However, author Charles Morris expertly illustrates how the tradition of innovation in America began just as the new country was getting started. Morris' recent book, *The Dawn of Innovation*, describes the transformation of a young nation from a minor player on the world stage at the opening of the 19th century to eclipsing the British Empire at the end of the century as the world's largest economy and manufacturer. Some of the more famous inventions marking America's developing industrialization include Robert Fulton's steamboat (1777), Eli Whitney's cotton gin (1793), and Samuel Colt's systemized manufacture of firearms with interchangeable parts (1836).

Morris, a distinguished banker and lawyer by trade, has authored more than a dozen books on American history, with an emphasis on events and personalities that had a profound influence on America's economic development. With the subtitle, "*The First American Industrial Revolution,*" his newest book provides an engaging account of the remarkable technologies, businesses, and distribution systems that were put in place across the American continent as settlements rapidly moved west by foot, wagon, boat, and rail.

Some key numbers tell the story. In 1800, Britain was the leading global provider of raw materials, such as coal and iron, as well as finished products, with America's output a mere one-sixth of that of the British territories. At the 1851 Great Exhibition of the Works of Industry of all Nations, held in London's Crystal Palace, Victorian England continued to celebrate its mastery of the world's economy — but the United States gained attention for its ability to mass produce interchangeable parts. Moreover, we were catching up; US production had grown to approximately 30% of the British output. In the 1880s, US output had achieved parity, and by the breakout of World War I, it exceeded British output by a factor of 2.3.

This catch-up century began with war preparations, a familiar boost to economic development. Morris describes the naval arms race during the War of 1812 (1812 –1815), in preparation for a major battle between the United States and Britain in the Great Lakes region. Because of its strategic location separating the US and Canada, both sides anticipated major military engagements on Lake Ontario or Lake Erie. In 1812, the US Navy had one ship supporting 16 guns and the British had six ships supporting 40 guns. By the end of this short war, their firepower was essentially equal, and more than 100 ships were armed and manned on each side of the lakes. Fortunately for the sailors in both fleets, there was never a major battle. (Note the uncanny similarity to the Cold War arms race between the United States and the Soviet Union that thankfully never culminated in attack.) The central reason that a significant battle never came to pass appears to be an asymmetry in the fleets' capabilities. The British were superior in sailing and maneuvering in stormy seas. The American fleet performed best in calm seas and it had amassed a larger quantity of long-range canons, which favored longer distance engagements. This disparity meant that no time was optimal for a good fight. The investment nevertheless proved profitable for America; the necessity to rapidly build up its fleet jump-started the shipbuilding and attendant industries, such as lumber and iron.

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Morris traces American industrial development in the 19th century through multiple pathways. Power generation sprang up on almost every stream east and west of the Appalachians. Water turbines were developed for major dams, which are still in use today for generating hydroelectric power. Shipping and transportation networks replaced horse and carriage with canals and steam ships. A rail system crisscrossed the nation by midcentury and quickly grew to an established railroad network, which is also still used today.

At the dawn of the 19th century, the United States was primarily a supplier of raw materials to Britain and the continent; it had to import most finished products. However, US industry quickly evolved beyond agriculture to basic household necessities such as clothing, furnishings, chemical products derived from agriculture (lard and whale oil), and then to the heavy industries that fueled (oil) and transported (steam engines, locomotives) the nation, eventually propelling the US economy to surpass Britain's. Along the way, a banking industry was established with an elite financier class, with the likes of Mr. Rockefeller, Carnegie, Morgan, and Vanderbilt, who reaped extraordinary fortunes from this exploding economy.

Much of the early development of these technologies and the underlying inventions, such as the steam engine and the Bessemer furnace for steel, were British born. What fed the American economy to grow so rapidly and overtake the mother country? Morris identifies three major factors at the beginning of the century that led to America's success: 1) near universal male suffrage for the predominant citizenry, leading to widespread participation in local and national government; 2) mass public education, fostering the growth of a significant middle class participating in the economy; and 3) a seemingly unlimited availability of natural resources from an untapped continent. Later, in the midst of the country's most trying period, the Civil War, President Lincoln's fractious Congress passed three pieces of legislation in 1862 that strongly underpinned the country's continued economic growth and prosperity as the war ended: the Homestead Act, the Transcontinental Railroad Act, and the Land Grant College Act. Few pieces of federal legislation before or since have had more effect on the American economy, with the exception of the "GI Bill" after World War II.

Morris completes his account of this first century of American innovation with what he characterizes as a prologue and epilogue. For the prologue, he recounts how the new American nation could reinvent the industrial revolution and out play Britain to become the world's economic tour de force. In his epilogue he contrasts this history with the current landscape, where the United States has taken the role of incumbent, facing a fast-growing China for 21st-century dominance. There are lessons unfolding on both sides of this economic race; we must consider the values of participatory democracy, a strong public education system, and respect for natural resources. And in this century, we must find a balance between economic power and global welfare.

\- H. Frederick Dylla

(*Editor's Note*: H. Frederick Dylla is the retired executive director and CEO of the American Institute of Physics. This review is reprinted, with permission, from the 10 March 2014 issue of *AIP Matters* and was also the basis for Dr. Dylla's review of the same book in the May 2014 issue of *Physics Today*.)

John MacCormick, *Nine algorithms that changed the future: the ingenious ideas that drive today's computers* (Princeton, Princeton, 2012). x + 219 pp. $27.95. ISBN 978-0-691-14714-7.

As MacCormick states on page 3, "an algorithm is a precise recipe that specifies the exact sequence of steps required to solve a problem." In this book he describes nine "great algorithms" – "great" in the sense that they meet the following four criteria: 1) they are "used by ordinary computer users every day," 2) they "address concrete real-world problems," 3) they "relate primarily to the *theory* of computer science," and 4) they have mathematical "beauty" (pp. 4-5). Because these criteria are clearly intertwined with computers, it's not likely that you'd want to read this book if you didn't use a personal computer, but you don't have to be a geek to appreciate what MacCormick has to say. Although he makes liberal use of such arithmetic topics as exponents and logarithms (more of the former than the latter), he writes for what might be termed the "lay" computer user, and – because he is so meticulous about including all the details, his descriptions are easy to follow and fun to read.

After his introductory chapter, the topics of the next nine chapters (which are followed by a brief conclusion) are his nine algorithms – actually eight algorithms and one problem that computers can't solve (more on that later). These algorithms are those used to match expressions entered into search engines with documents being searched (chapter 2), rank websites that meet the criteria for an entry in a search engine (chapter 3), transmit information securely between a sender and receiver (chapter 4), detect and correct an error in a message (chapter 5), make decisions (the ultimate goal of artificial intelligence) (chapter 6), compress data (chapter 7), manage data bases (chapter 8), and authenticate a document (digital signatures) (chapter 9). In contrast to all the previous chapters, which describe things computers *can* do,

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the tenth chapter shows that, through proving something by showing that its negative leads to a contradiction, it is impossible to write, among other things, a computer program that identifies all the bugs in another program that could cause it to crash. As one knows from trying to follow the logic of a double negative, the reasoning here becomes a little tedious, so the level of fun for this penultimate chapter is not as great as for its nine predecessors.

Normally when I write reviews for this column, I try to give the reader the essence of the book, and I could provide more detail here by sharing the paragraph of notes I took for each of chapters two through nine. But I felt that I'd need to precede each paragraph by a "spoiler alert" notice, because it would spoil the enjoyment you would get from working out the examples with MacCormick. Instead of doing this, I recommend that, if you're interested in what MacCormick calls the "tricks" computers use to accomplish the goals of chapters two through nine, you should get a copy of his book and share the fun of working through each example.

\- John L. Roeder

Michael A. Levi, *The power surge: energy, opportunity, and the battle for America's future* (Oxford, Oxford, 2013). 260 pp. $27.95. ISBN 978-0-19-998616-3.

In our Fall 1995 issue I reviewed a book by Christopher Flavin and Nicholas Lenssen with the same title. It argued that an energy future based on fossil fuels was unsustainable and that a new energy revolution based on conservation and renewables was brewing to replace them. Thus, Flavin and Lenssen gave their book the subtitle, *Guide to the Coming Energy Revolution*.

In his Acknowledgments to *his* portrayal of America's energy future, Levi states that he wrote his book because he couldn't find one "across economic, security, and environmental challenges and opportunities." (p. 211) Thus his subtitle is also an appropriate one, particularly in his choice to use the word, "opportunity," which is the context in which he views the decisions America must make in creating its energy future.

In his first chapter, titled "The Battle for the Future of American Energy," in which he sees the two sides as fossil fuels and renewable energy sources, Levi sets the scene for addressing energy issues in terms of a "classic trio of concerns – economics, security, and environment" (p. 16) – and chooses to focus on the following three questions: 1) "Does each energy source . . . offer important opportunities to improve the U.S. economy, strengthen national security, or mitigate climate change while not causing intolerable damage on any of those fronts?" 2) "Is it possible to seize those opportunities simultaneously – or would pursuing some of them severely undermine the others?" 3) "Can the United States take advantage of these opportunities without fundamentally altering the role of government in American society?" (pp. 18-19) In doing this, Levi asks us to consider the possibility that both approaches to energizing our society can provide benefits.

The next two chapters focus on the possible role of fossil fuels in our energy future, with special emphasis on recent developments in producing natural gas from hydrofracturing and oil from shale and tar sands, the combination of which can make the U.S. independent of fossil fuel imports or at least less dependent on them. Then in his fourth chapter he recognizes that the threat of global climate change from fossil fuels is blowing the whistle on their combustion in the future. This is particularly critical for transportation, the subject of his fifth chapter, where he concedes that even in alternatives to direct use of fossil fuels there is still dependence on them – for fertilizer to grow biofuel crops or to produce electricity – only using less energy or using it more efficiently can provide a real hedge against climate change.

Thus in his sixth chapter he considers alternatives to fossil fuels. Although nuclear is included here, most of the chapter focuses on renewables. After a penultimate chapter on future world oil production, Levi considers the following current energy opportunities: 1) plentiful natural gas, 2) increased oil production, 3) improved transportation technology, and 4) lower cost renewable energy, all of which have important contributions to make to our energy future.

Mindful that an optimum energy future for America will require some governmental involvement but that too much or the wrong kind could be deleterious, Levi advocates "a strategy that increases opportunity while protecting against important risks." (p. 199) He feels that this is embodied in four "rules":

1) "Build a diverse and resilient energy portfolio." (p. 199) In the face of uncertainty about the future, it is good to have more than one approach to facing it. (Levi cites this as an example of the way the Defense Department plans for whatever contingencies may occur, an approach seen by some as wasteful and duplicative.)

2) "Focus on big wins." (p. 201) By "big wins" Levi means "big gains for the economy, security, or the environment" (p. 201) ("Overly aggressive fuel economy mandates" (p. 202) fail here, because they reap environmental and security gains at great economic cost. So too would oil drilling that produced economic gain at too great an environmental cost.)

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3) "Empower energy development." (p. 203) Given the many competing aspects of energy development, achieving this requires a balance between facilitating collaboration and streamlining permits, on one hand, and minimum standards and environmental safeguards, on the other.

4) "Leverage gains at home to make progress abroad." (p. 203) Marketing shale gas technology and technology for renewable energy and energy efficiency would make the U.S. a major player in the world energy market and could lead the world by example to reduce its greenhouse gas emissions.

Levi concludes with one final plea to pursue all the opportunities for America's energy future, for only then will no opportunity be lost.

- John L. Roeder

Jonathan, Waldman, *Rust: The Longest War* (Simon and Schuster, New York, 2015). 288 pp. (hardback) ISBN 978-1-4516-9159-7 (hardback), 978-1-4516-9161-0 (ebook).

Really now, a book about oxidized ferrous metals? That question did not occur to this reviewer when he had heard the author interviewed on National Public Radio. Thanks to Amazon Prime, the book arrived at my home two days later. *Rust: The Longest War* contains chemical information, but it is not a science textbook. Among other reasons to examine the topic, admitting its lack of drama, Waldman explains that the cost "…sneaks below the radar…But rust is costlier than all other natural disasters combined, amounting to 3 percent of GDP, or \$437 billion annually…That averages out to about \$1500 per person every year." He points out that besides iron's vulnerability to rust, not only iron and steel but almost every metal is subject to corrosion, often creating vivid colors when it occurs.

Many problems of America's deteriorating infrastructure hide from view, such as corroding bridge beams, reinforcing bars deep inside concrete foundations, and century-old water and sewer pipes ready to break. Branches of the nation's military devote vast sums to repairing and protecting ships, land vehicles, airplanes, weapons, and structures from damage. The author surveys a mix of corrosion problems and partial solutions, but also focuses on sometimes-quirky personalities of the enemies of rust. Each chapter tacks to a surprising destination or topic unlike any previous content.

The introduction deserves careful reading. Here is a sample quotataion:

> Rust has knocked down bridges, killing dozens. It's killed at least a handful of people at nuclear power plants, nearly caused reactor meltdowns, and challenged those storing nuclear waste. At the height of the Cold War, it turned our most powerful nukes into duds. Dealing with it has shut down the nation's largest oil pipelines, bringing about negotiations with OPEC. It's rendered military jets and ships unfit for service, caused the crash of an F-16 and Huey [helicopter], and torn apart the fuselage of a commercial plane mid-flight. In the 1970s, it was implicated in a number of house fires, when, as copper prices shot up, electricians resorted to aluminum wires. More recently, in the 'typhoid Mary of corrosion,' furnaces in Virginia houses failed as a result of Chinese drywall that contained strontium sulfide. They rusted out in two years. One hundred-fifty years after massive ten-inch cast iron guns attacked Fort Sumter, rust is counter-attacking. Union forces have mobilized with marine-grade epoxy and humidity sensors. Rust slows down container ships, before stopping them entirely by aiding in the untimely removal of their propellers. It causes hundreds of explosions in manholes, blows up washing machines, and launches water heaters through the roof, sky high. It clogs the nozzles of fire sprinkler heads: a double whammy for oxidation. It damages fuel tanks and then engines. It seizes up weapons, manhandles mufflers, destroys highway guardrails, and spreads like a cancer in concrete. It's opened up crypts.

The first chapter covers a criminal trespass case about about an English climber who had mostly failed to climb the exterior of the Statue of Liberty. His suction cups failed to adhere properly because of too many small holes in the penny-thick copper skin. Waldman leads the reader through a tale of serendipitous discovery to find that the holes should have held rivets. Decades of bad decisions about multiple coats of paint on the inside of the copper had trapped water that corroded the rivets. Paris's engineer Eiffel and the statue's builder, Bartholdi, had both known of the risk of galvanic corrosion based on contact between the iron interior framework and the copper exterior so near a body of salt water. Later caretakers of the statue, however, failed to consider the electrochemical hazard. By 1980, less than a century after its placement, the symbol of liberty and friendship between two nations was nearing collapse. The chapter charts the clumsy, almost comically inept efforts to diagnose the specific problems and then restore the glory of the beloved monument.

The next chapter sets forth a compact historical survey of rust reports and research. One Roman general complained of rust problems with his huge catapults. Pliny the Elder opined that nature balanced the beneficial power of iron by imposing rust to limit its capacity for inflicting harm. He coined a Latin term here translated as "Spoiled Iron." In the 17^{th} century Robert Boyle's extensive studies of rust offered little understanding compared with his achievement with the gas laws. His observations on applying various acids, bases, and organic substances to familiar metals showed that tin, antimony, silver, and

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others responded with forms of corrosion. Even gold suffered from a mixture of nitric and hydrochloric acid. Only a few rare earths — tantalum, niobium, iridium, and osmium — are truly corrosion-proof metals. In Waldman's definition "Rust, of course, is the corrosion of iron, while corrosion is the gnawing away, thanks to oxygen, of any metal. To the horror of engineers, I use the word colloquially." Indeed, a brilliant engineer friend and enthusiastic reader, at my recommendation, gave the book a cursive look but soon put it away. I would guess that physicists and chemists, however, would enjoy this chapter at least as much as I did.

Beginning appropriately in Sheffield, England, the story of stainless steels unfolds along with the life of Harry Brearley in 1913. As is often true with inventions, at least ten others had developed or contributed to this rust-resistant material, but the author gives Brearley much of the praise for its adoption and distribution. Waldman has a generous way of giving due recognition to a variety of participants, describing personal traits and oddities that enrich the story. He avoids either over-glamorizing or vilifying people, even when the reader might be tempted to assign grades to those taking part. He even shows respect for a woman whose spare time is spent in a quasi-career of photographing "the rustiest place in America, [which] is not open to the public." That would be what was once the world's second-largest steel producer, the Bethlehem Steel Works, in its namesake town in Pennsylvania before it went cold in the 1970s. One winter he dodged patrols with her as she made a mostly-illegal trek through the gigantic, silent structures making some of her thousands of photographs of the colors and other manifestations of rust. She produces and sells large photographic prints of the art of rust. *The New York Times* once featured an eight-page spread of her photos.

Who would have imagined the scary story of container coatings that Waldman tells? As the author reveals it, if they don't explode first, over time most foods and beverages would react with (read "leach, damage, or destroy") their metal containers. In the 19th century a coating of tin delayed the process. Later, different materials would replace the inside coating. In a kind of industrial spy maneuver the author managed to attend Can School, which is sponsored by the largest maker of cans, Ball. That name is one long associated with home canning jars and lids. More than a century had been needed to perfect a can for beer, plus another generation to establish aluminum as the metal of choice, and still longer to make such cans a standard for sodas.

> Consider a can of Coke. It's a corrosion nightmare. Phosphoric acid gives it a pH of 2.75, salts and dyes render it still more aggressive, and the concoction exists under ninety pounds per square inch of pressure, trying to force its way out of a layer of aluminum a few thousandths of an inch thick. It sits there for weeks, months, years, often in a humid fridge, or dark pantry, or hot trunk, or stagnant warehouse.... That the can doesn't corrode is a technological marvel....All that protects the meager aluminum is an invisible plastic shield.... This plastic must be tough but flexible. It also must be rheologically suitable in terms of viscosity, stability, and stickiness. Without the epoxy lining, only microns thick, a can of Coke would corrode in three days. Our stomachs are stronger than the aluminum. But it's becoming increasingly evident that other parts of our bodies may not be stronger than what's in the epoxy. That's why the beverage container industry would rather not talk about rust, and why I nearly got kicked out of Can School.

I never drink sweetened sodas or anything else from cans, but after reading this book, if I did, I would quit overnight. "Coatings" has become a dirty word for me. Your experience may vary.

The final, lengthy chapter provides massive detail — maybe too much but perhaps not since the Keystone XL pipeline has been canceled — about the Alaska Pipeline (TAPS=The Alaska Pipeline System). As a one-time Alaska resident, I found this chapter worth the price of the book, a splendid example of top-quality journalism. There is a most revealing account about the high-tech inspection "pigs" sent at times through the 800-mile-long four-foot-diameter Alaska Pipeline. It had never occurred to me that *internal* corrosion of the pipe would be such a major problem. Also, it was a surprise to learn that a buildup of wax on the pipe's inner surface would limit the ability of the pigs to gauge thickness of pipe at various sites. Declining flow from an aging North Slope field creates new problems. Knowledge gained in this challenging terrain has benefited other pipeline buildings around the world. Waldman's respect for his Alaskan and other interviewees comes through without blindness to their limits. This is a fair, thorough, very readable book that I can recommend without hesitation to scientists, engineers, and amateur STEM enthusiasts like me.

\- John D. White

Your book review here!

Have you read any good books on how an aspect of science is related to society lately? Send a review to JLRoeder@aol.com for publication in our next issue!

Musings

by REY

Science Teaching Should Change Just as Science Does

by Robert E. Yager

That the 1996 National Science Education Standards (NSES) were sixteen (16) years old in 2012 resulted in calls for *New* Standards. A new Framework for organizing the New Standards was completed by the National Research Council (NRC) with generally positive results. "New" Standards were completed in 2013, using the approved Framework. But, there were calls for suggestions for changes before New Standards were published in final form and offered to all as new directions for science education reforms.

One of the major changes is the omission of the first four facets of the "old" Standards. When questioned, the New Standards team reported: "Why change what seems to be as timely now as 16 years ago?" These old – but not-to-be changed – features for science education reform include: 1) Goals; 2) Teaching; 3) Professional Development; and 4) Assessment. Of the four, "Teaching" is often seen as the most important – and not to be revised or changed for the New Standards – now called "Next Generation Science Standards (NGSS)." The most conflict will likely continue primarily over what should be taught rather than how it should be taught.

The "old" Standards include but nine features to indicate how teaching should change from the "typical" teaching found in 90% of the K-12 school classrooms across the U.S. (and maybe the whole world!). Interestingly, these teaching standards were developed early during the four developmental years of the "old" Standards (1992-1996). There was literally no disagreement about the needed changes in teaching. In fact, the debate centered almost wholly on the definition of the science curriculum – *i.e.*, the "discipline" content that was to be included and used in K-12 schools. This resulted in major debate for four years, involving both scientists and educators. In many respects this focus on Content remains as the most difficult to revise for the 2013 Standards. Certainly more effective teaching is vital if we are to accomplish major reforms.

If there is general agreement concerning the nine ways school science should be approached, why are there no more efforts for accomplishing the "agreed upon" ways to describe more exemplary teaching? Perhaps these changes in teaching would result in clearer ideas about Content for inclusion in K-12 science classrooms and how it could be developed in multiple ways. This would result in actions and evidence that the current STEM efforts could be more successful than were the 1996 visions.

Perhaps we all should encourage and assist with the NGSS! However, could it not include a focus on improving teaching that could be moved "up-front"? If there is to be only little effort to improve science teaching, why not at least work for ways to realize the teaching advocated and supported by the 1996 NSES? Why not now? If teaching were to change, perhaps new ideas and suggestions for new course Content would be easier to formulate and actually used by all teachers in all schools. It could be a way of accomplishing improved teaching and the likely development of more positive student attitudes that result in increasing student learning. This would be learning that relates to accomplishing each of the four NSES goals! It would also provide significant changes in science teaching! *Musings* may lose their purpose without realizing real learning and accomplishing the reforms that involve student questions, ideas, and actions. Should not these characterize the NGSS which are in progress?

(*Editor's Note*: Robert E. Yager is Professor of Science Education, University of Iowa. He is a past contributor to this *Newsletter*, past President of the National Science Teachers Association and of the National Association for Science, Technology, and Society.)

Rowan Fossil Quarry

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Rowan University's future plans after it fully acquires the site include working with the Township and Gloucester County to establish a center for STEM (Science, Technology, Engineering, and Mathematics) education and "citizen science." Park-like settings on the old quarry will provide walking trails with signage that explains the Geologic Time Scale, the importance of South Jersey in the history of Paleontology, and other informal science learning opportunities.

More information is available at <http://rowan.edu/fossils> and <http://facebook.com/MantuaTownshipFossilHeritage>.

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Myths and Stories

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In some classes students retell the myth, develop class plays, and continue research into the different genres of myths and stories. This offers time for teamwork and also movement in class as students act out the story, retell it in a different language, develop images, or place it on white boards or iPads.

Related and interesting research may offer indications of how stories and myths "travel" and change over time. According to Jamie Tehrani, anthropologist of Durham University in England, stories from Europe, Africa, and Asia indicate that the story of Little Red Riding Hood starting to her Grandmother's House began in Europe and then traveled east. Tehrani analyzed 72 cases and studied how stories acquire traits that can change over time. He concluded that this story traveled east sometime during the 12th to 14th centuries.

In the use of all myths in the classroom, there is an opportunity to understand that humans always seek answers to questions about the world and its meaning, "seeking patterns to inform and protect us . . . need to encourage my students to figure things out, ask good questions, and find reliable information from which to construct answers." [Carol Ann Tomlinson, "Being Human in the Classroom," *Educational Leadership*, p. 76 (2015)].

"Human beings have always been mythmakers," writes Karen Armstrong in *A Short History of Myth* (Canongate U.S., 2006), her concise yet compelling investigation into myth: what it is, how it has evolved, and why we still so desperately need it. She takes us from the Paleolithic period and the myths of the hunters right up to the "Great Western Transformation" of the last five hundred years and the discrediting of myth by science. The history of myth is the history of humanity, our stories and beliefs, our curiosity and attempts to understand the world, which link us to our ancestors and each other.

Rowan Fossil Quarry

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The importance of providing science field experiences to learners of all ages cannot be overemphasized. No classroom or virtual reality can truly substitute for traveling to a location, walking to an anticipated location where something special awaits the visitor, and immersing oneself for a short time in scientific-style activities. There are many fossil parks across the country, but few like the Rowan Fossil Quarry, where children and adults can view an active excavation site, imagine what the researchers will uncover as they continue the work, and search the adjacent layers for a "treasure" they themselves discover and take home.

Pew Research Center surveys science literacy

The most recent report of American science literacy, a subject of ongoing concern in this *Newsletter*, is a survey in August-September 2014 of 3278 American adults by the Pew Research Center. Of the twelve questions they were asked, more than half could answer nine correctly. They could identify the hottest layer of the Earth, the element required for nuclear energy and weapons, the primary cause of ocean tides, the developer of a polio vaccine, the types of waves used to transmit cell phone messages, and what a light-year measures. They could distinguish a comet from other astronomical objects in terms of pictures and astronomy from astrology. They could also ascertain the meaning of a graph. But only less than half could identify the paths of light rays through a magnifying glass, the property of a sound wave which determines its loudness, and the dependence of the boiling point of water on altitude.

The report from the Pew Research Center, which presents the statistical details on responses for each question and the mean scores for groups according to education, gender, age, and race, is available online at <pewinternet.org/2015/09/10/what-the-public-knows-and-does-not-know-about-science/>. This report also contains a link for readers to take the actual quiz.

USDOE Develops Videos and Course on Energy Literacy

The Spring 2012 issue of this *Newsletter* reported on the Energy Literacy Initiative launched by the US Department of Energy and the American Association for the Advancement of Science (AAAS). The Department of Energy has now developed series of YouTube videos and a course, called Energy 101, based on the seven principles of energy literacy.

One video series, which can be accessed by Googling "energy literacy videos," is matched directly to the seven energy literacy principles and presents all the subprinciples for each principle, as listed in the Spring 2012 issue of this *Newsletter*. The other series is a larger number of shorter videos, designed to be used in the Energy 101 course based on the seven energy literacy principles. Both the videos and the course outline can be accessed by Googling "energy 101." The five parts of the course are 1) Introduction to Energy, 2) Energy Basics, 3) Energy Sources, 4) Energy Technology and Practice, and 5) Energy Policy and Decision Making.

(*Editor's Note*: Anyone desiring a pdf of the Spring 2012 issue of this *Newsletter* can obtain one by requesting it of <JLRoeder@aol.com>.)

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Window to the Past in a Marl Pit—The Rowan Fossil Quarry

by Michael J Passow
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Throughout the 1800s, into the 1900s, and occasionally even today, quarries in Central and Southern New Jersey dug up marl for use as a soil conditioner. This crumbly mixture of calcium carbonate and clay was valued by farmers across The Garden State because it also provides phosphorus, manganese, and other elements. But at one location in the small town of Mantua, a marl pit is revealing more than the promise of good crops. Fossils of many invertebrate and vertebrate species have been uncovered in a thin layer far below the present ground level. This fossiliferous zone may provide a unique glimpse of what happened "One Bad Day" some 65 million years ago.

Fossils are not uncommon in southern New Jersey. One of the first dinosaurs, *Hadrosaurus foulkii*, was discovered in nearby Haddonfield. *Dryptosaurus,* a tyrannosaur, was uncovered in 1866 on the site of what today is a Mantua park. The Inversand Company began marl quarrying about a century ago, and, beginning in the 1920s, thousands of fossils were being uncovered in the pit from a layer that is only 15 cm (6 in) thick. Most abundant are such marine invertebrates as clams, oysters, snails, brachiopods, and bryozoans. Also commonly found are several species of shark teeth and coprolites (fossilized dung). Less common were fish teeth, sturgeon scales, and bones of various vertebrates, including fishes, and sea turtles.

But the true prizes were bones from marine crocodiles, mosasaurs, and dinosaurs. Researchers associated with Rowan University have been carrying out careful excavations of the site to try to ascertain whether the micropaleontology, geochemistry, and other lines of evidence definitively link this "kill site" with the global mass extinction event associated with the famed asteroid impact that ended the Mesozoic Age of Reptiles and opened the way to the Cenozoic Age of mammals.

Spearheading the efforts is Dr. Kenneth Lacovara, a distinguished paleontologist known for discovery of giant dinosaurs, including *Dreadnaughtus.* He was appointed last September to the combined positions of founding Dean of the Rowan University School of Earth and Environment, and Director of the Rowan Quarry. In his previous position at Drexel Univeristy, Dr. Lacovara conducted research at the site for more than a dozen years. Now that the Inversand Company is closing commercial quarrying, he is arranging purchase of the 65 acre site (25 hectares) by Rowan University. Dr. Lacovara is working closely with the University, Mantua Township, and Gloucester County to develop programs and facilities that will combine scientific research with exciting educational outreach.

Every other Friday during the fall and spring, hundreds of school children arrive by bus and walk down into the pit. At the final day for this season, I watched Dr. Lacovara welcome more than 450 children and teachers from area schools with a brief explanation of what makes the area of special interest, as he stands on a large pile of sediments. He then turns the kids loose with plastic shovels, screen sieves, bags, and high hopes that they will find some shells, a fragment of iron minerals, or other interesting objects to take home. They dug, they sieved, they talked, and for about an hour, they "scienced." They and their teachers returned to their schools excited to follow up on the experience through readings, writings, drawings, and other learning activities.

Volunteers from Mantua and other local communities work with Dr. Lacovara and Rowan University to make these visits enjoyable for schools throughout the area. It has become so popular that the waiting list for future visits now has more than 80 schools. The site was opened for a "Community Dig Day" in the fall, and organizers had to cap participation at 1,500, with an equal number on the waiting list. (That's approximately 20% of the estimated population of Mantua.) Since 2012, more than 10,000 visitors have come to the Fossil Quarry.

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