TEACHERS CLEARINGHOUSE

FOR SCIENCE AND SOCIETY EDUCATION

NEWSLETTER

Vol. XXXV, No. 2
Fall 2016

Gershenfeld sees parallel between digital communications and fabrication

by John L. Roeder

One of the plenary speakers at the summer meeting of the American Association of Physics Teachers (AAPT) in Sacramento (CA) was Neil Gershenfeld, director of the Center for Bits and Atoms at MIT. He spoke on 19 July 2016 on a subject related to the center he directs, "From Bits to Atoms." After he began by reviewing the early contributions to computing and communications by Alan Turing, John von Neumann, and Claude Shannon, he seemed to shift into some kind of duality between computing and fabricating, but I found that I was unable to keep up with him in my notetaking.

Then, toward the end of his talk, things started to become clear again. He had set up a series of "Fab Labs" to allow users to directly fabricate things with a wide variety of machines, the most used of which was the laser cutter (while the 3-D printer was used only 20% of the time). When I heard him close by quipping that people working at these Fab Labs were often viewed as troublemakers elsewhere, I reasoned that he had done a good thing and regretted that I had been unable to keep up with what he had said between the beginning and the end. I also thought that if I could read his writings, I could take in his ideas at *my* pace rather than at the rather fast pace of his talk – and even shared this idea when I saw him later (he encouraged me to check out his website).

I fortunately was able to locate a copy of his book, *Fab: the Coming Revolution on Your Desktop – from Personal Computers to Personal Fabrication* (Basic, New York, 2005), and reading it persuaded me that he indeed had some very profound things to say. He begins his first chapter by noting that the transition from mainframe computers to PCs transformed our world of *bits* (John Tukey's contraction of "*bi*nary digi*ts*"). He goes on to add that the transition from machine tools to personal fabricators is transforming our world of *atoms* (hence the title of his talk). "At the intersection of physical science and computer science, programs can process atoms as well as bits," he writes (p. 4). "Ultimately, this means that a programmable fabricator will be able to make anything, including itself by assembling atoms." (p. 4) Gershenfeld likens personal fabricators to *Star Trek*'s replicator and the Nutri-Matic in *Hitchhiker's Guide to the Galaxy*.

Gershenfeld relates how he and his colleagues at MIT's Center for Bits and Atoms started by assembling "an array of machines to make the machines that make machines" (p. 5) and in 1998 taught a one-semester course called "How To Make (almost) Anything," intended for students who would use these machines in their research. Instead they had ten times the expected enrollment, but of students interested in making things of personal rather than of professional interest. They succeeded in making them because of their persistence and their willingness to share with each other what they had learned about running the machines. Gershenfeld calls it "just in time" rather than "just in case" education. He saw in this student reaction a return to the days before mass production, when tools were developed by their users as they were needed.

Gershenfeld likens the machines his students worked with to mainframe computers. Just as VisiCalc made the Apple][a staple business tool and Lotus 1-2-3 did the same for PCs, and integrated circuits enabled development of the PC, he feels that the transition from these machines to a desktop personal fabricator will be enabled by an invention that prints "functional" materials – insulators, conductors, and semiconductors are cited as examples. Just as living organisms contain in their genetic code the instructions for their assembly, Gershenfeld foresees a "digital fabrication process based on programming the assembly of microscopic building blocks . . . embodied in personal fabricators" (p. 10) and also able to correct errors.

The precision of a micron in a CD player and of a microsecond in a computer chip tells us the precision that a personal fabricator can achieve. Since the PDP-5 minicomputer foretold the ultimate use of the PC, Gershen-

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Letters to the Editor

Dear John,

Thanks for sending the Teachers Clearinghouse for Science and Society Education *Newsletter* for Fall 2015 around to the physoc group. The articles are always of great interest, and pertinent to physoc interests. I especially appreciated your report on James Hansen's talk (page 3). I made a copy of that article and sent it out to two global warming discussion lists in Northwest Arkansas. I'm attaching a pdf of that copied article (with credit to Teachers Clearinghouse) below, for those who might have missed it in the newsletter or who would like an electronic copy to send out to others.

It's notable that, according to Hansen, sea levels during the Eemian era 120,000 years ago (the interglacial period between the last two ice ages) were five to nine meters higher than today although the temperature was only one Celsius degree higher than today. This implies that sea levels will be a whole lot higher when the planet finally reaches equilibrium with all the CO_2 that we continue dumping into the atmosphere. We have indeed initiated a new geological era.

Cheers, Art Hobson
18 Jan 2016

In the Winter-Spring 2015 issue there was a grand article on Indigo and Cochineal: Uniform Colors by Robert Drake. As an old herbal person I appreciated this article so much — so well based and written — science, history, art, even molecular structure. Better than any article I have read in our herbal journals! Perhaps not universally interesting, but I commend you for including something like this as well as more "science - physics" foci. I have and intend using this in many ways.

I have long been lured about colors/pigments/light in our daily lives - the history, development, understanding - the road to today's analine dyes and their impact. Natural dyes offer a myriad of opportunities for making science-society connections and always make for fascinating reading too as well as hands-on investigations and motivating interest.

Jane Konrad
27 July 2016

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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>.

Making Progress toward Teaching NGSS-Aligned Earth Science Education

by Michael J. Passow, Earth Sciences Correspondent

Teaching Earth Science at any level — from Pre-K to University courses — using an NGSS approach cannot be accomplished as a solo act. Of course, unless the structure of schools changes drastically, most teachers will still be solo performers in their classroom. But helping them prepare for student achievement in NGSS-aligned programs will require "a community." So what progress is being made toward this goal?

The Science Education Research Center (SERC) at Carleton College and the National Association of Geoscience Teachers (NAGT) have organized two Earth Educators Rendezvous (EER). (http://serc.carleton.edu/earth_rendezvous/index.html). The inaugural 2015 EER in Boulder brought together science education practitioners and researchers focused on undergraduate programs. The 2016 EER expanded the audience to include 12 teachers, graduate students, and college faculty from all disciplines interested in teaching about the Earth System.

Oral, poster, panel, and plenary sessions were designed to help participants gain greater understanding of new instructional approaches, research opportunities, and teaching and learning challenges. The five-day program provided a wide range of examples of tested instructional strategies shown to improve student learning. Some addressed challenges specific to particular settings (*e.g.,* field or large class size), topics (*e.g.,* sustainability), and skills (*e.g.,* spatial reasoning).

The EER recognized that not only current teachers benefit from such advice, but also that to work toward future NGSS-aligned success, graduate students and post-docs preparing for academic careers will need help. Among other EER goals were recognition of the importance of collaboration across disciplines to situate learning about Earth in societal context, and of solid research to support these efforts.

You can see more details about the 2016 Technical Program at <http://serc.carleton.edu/earth_rendezvous/2016/program/index.html>.

Planning for the 2017 Earth Educators Rendezvous is already underway. It will be held at the University of New Mexico in Albuquerque 13-17 July 2017. Updates will be available at <http://serc.carleton.edu/earth_rendezvous/2017/index.html>.

More evidence of progress toward teaching NGSS-aligned programs was evident in the presentations made at the recent Geological Society of America annual meeting. Technical Session 85 provided 21 examples of "Planning to Make a Difference through the Next Generation Science Standards."

The morning session opened with an update on progress in adopting and adapting the NGSS across the Nation by Dr. Michael Wysession, one of the key proponents for Earth Science Education during development of the NGSS. Other speakers discussed progress in creating pre- and in-service teacher preparation programs, developing useful resources through the CLEAN and other online collections, and summer and academic year opportunities for high school students to engage in authentic research where they learn about Science and Engineering Practices and experience the Nature of Science. Abstracts and other resources from this session are available at <https://gsa.confex.com/gsa/2016AM/webprogram/Session40400.html>.

The afternoon session provided a potpourri of examples of programs testing out how to meet the spirit of NGSS learning. Topics included improving pre-service K–5 teacher self-efficacy, writing and information literacy, multistate teacher collaboration, and other themes. The session concluded with an inspiring Prezi-based talk by Don Duggan-Haas of the Paleontological Research Institute entitled "What Is Different This Time? The NGSS, Prior Educational Reform Initiatives, and Thoughts on Averting Another Failed Reform Effort." You can read abstracts from this session at <https://gsa.confex.com/gsa/2016AM/webprogram/Session41391.html>.

One final area of progress to report on comes from State efforts to develop models of curricula that teachers can build from in designing their own courses. The State of New Jersey has created one such suite of "Model Curriculum" units. They are found at <http://www.state.nj.us/education/modelcurriculum/sci/>.

Earth Science topics are interwoven in the Kindergarten–Grade 8 units and form parts of the Capstone Science examples. These 2- to 5-week units include designs for teacher "Chemistry of the Universe"; "Planetary Motion"; "Physics of the Earth"; "Dynamic Earth Systems"; "Human Activity and Climate System"; "Human Activity and Sustainability"; and "Human Activity and Energy." More details of these are available at <http://www.state.nj.us/education/modelcurriculum/sci/capstone.shtml..

In short, progress is being made. What can you contribute toward future achievements?

Pompea emphasizes importance of problem solving

In the lecture following his receipt of the 2016 Millikan Medal of the American Association of Physics Teachers (AAPT), Stephen Pompea of the National Optical Astronomy Observatory in Tuscon (AZ) spoke about the importance of problem solving in his life. In a talk titled "Knowledge and Wonder: Reflections on Ill-Structured Problem Solving" on 19 July 2016 to the AAPT at its summer meeting in Sacramento (CA), he began by citing four characteristics of hard problems: 1) The solution depends on how the problem is framed. 2) Stakeholders have different perspectives. 3) Constraints may change. 4) The problem is never definitively solved. They are frustrating, he said, but worth solving. Consequently, he advocates exposing students to problems early as a way to motivate their development of problem-solving skills.

Pompea went on to note that his first problem at Martin Marietta was to extend the wavelength range for a coating on the InfraRed Astronomy Satellite from 5 to 500 microns – his solution was to cover it with roughened aluminum oxide. When later in life he sought to make improvements to education, he found that he was faced with more difficult problems. One of his solutions was to build the Astronomy Village for the College of the Future in West Virginia in 1995. It featured Netscape and included simulated e-mail. After availing themselves of the equipment in the Village to investigate their problem, students were expected to produce a report. Other problems and projects which Pompea faced were developing the Galileoscope and restricting waste light vented to the sky (which obscured astronomical viewing).

California's Coping with Climate Change

Guido Franco of the Research Division of the California Energy Commission spoke about "Climate Change and California: Potential Imports and Solutions" to the American Association of Physics Teachers on 19 July 2016 at its summer meeting in Sacramento (CA). Franco began by recounting that California began considering climate change in 1988 and subsequently created the California Climate Change Research Center, tasked to implement a 2003 research plan. A report on the current effect of climate change on California is now mandated every three years.

Franco noted that both 2014 and 2015 produced annual average temperatures greater than would be expected from normal temperature variability. Moreover, the percentage of annual water runoff, due to early snowmelt, has been decreasing the past 30 years, and sea level has increased by 40 cm since 1860. Habitat for flora and fauna have shifted accordingly, he added, expressing the hope that limiting further greenhouse gas emissions can delay continuation of these trends.

The Research Center integrates the projected changes with socioeconomic scenarios to predict future need for electrical energy generation and future need for wildfire protection, Franco continued. He went on to add that California is planning to phase out its nuclear power reactors and legally requires that half its electrical energy generation come from renewables by 2030. Their latest plan is *Safeguarding California: Reducing Climate Risk*.

Climate Change Films for the Classroom

Jeffrey Groff from Shepherd University in Shepherdstown, WV, spoke on "Climate Change Films for the Classroom" to the American Association of Physics Teachers on 19 July 2016 at its summer meeting in Sacramento (CA). He reported that he had learned about these films at the American Conservation Film Festival and felt that they are good ways to engage students about climate change in the classroom. They are accompanied by Instructor Screening Guides which summarize the film and suggest accompanying classroom activities.

Among the films cited by Groff were

- *Switch* (2013 festival) – on switching to electrical energy generation by renewables
- *Pandora's Promise* (2013) – asking whether climate change risks justify more nuclear energy
- *Chasing Ice* (2015 festival) – on retreating Arctic glaciers
- *Merchants of Doubt* (2015 – Green Fire Award) – on the spread of misinformation (inspired by the book of the same title, reviewed in our Winter 2012 issue).

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Wertheim shows fascination with space

Margaret Wertheim, recipient of the 2016 Klopsteg Memorial Lecture Award from the American Association of Physics Teachers (AAPT), works at the intersection of science, math, art, and environmentalism. After studying physics for six years, she decided to become a science communicator and write about science in a cultural context and to do so outside the literature read mostly be scientists. She even persuaded *Vogue* to let her write a column in science and technology – and she said that this was much more difficult than writing even for *The New York Times*. As opposed to think tanks, Wertheim advocates "play tanks," a place to play with ideas. Her log is "*fig*," based on the multiple roles of the word, "Figure," and she has named her affiliation the Institute for Figuring.

In her lecture to the AAPT at their summer meeting in Sacramento, CA, on 18 July 2016, Wertheim showed her fascination with the concept of space, which she observed is much different today than centuries ago. Then it was all based on the geometry of Euclid, which Roger Bacon used for geometric figuring in the thirteenth century. But, she noted, the advent of non-Euclidean geometries in the nineteenth century enhanced our acceptance of them in nature, whereas only a century before they had been a source of pain. Two non-Euclidean geometries which she cited in particular were hyperbolic (with negative curvature) and spherical (with positive curvature). She saw in the fact that coral reefs and the flowers in *Avatar* are based on hyperbolic geometry examples of Nature's "romance" with hyperbolic geometry in many plants – and in the coral reefs she found a connection to environmentalism, because climate change is destroying them. She added that carbon comes in all three geometric forms – fullerines (spherical), carbon nanofoam (hyperbolic), and graphite (Euclidean).

Wertheim pointed out that the two curved geometries and Euclidean geometry have different consequences for parallel lines, and she showed this physically by crocheting a hyperbolic surface and sewing straight lines on it. Such crocheting done by her and her sister has been displayed in many art museums and used to teach many women about the mathematics and science of coral reefs, she said.

Two Speakers Explore Two Aspects of SETI

Two speakers at the summer meeting of the American Association of Physics Teachers in Sacramento, CA, spoke about two different aspects of the Search for Extra-Terrestrial Intelligence (SETI) at a session on 18 July 2016. The first, Andrew Siemion of the University of California-Berkeley, reported on the Breakthrough Initiatives, a $100 million effort to search 100 million stars in our galaxy and 100 nearby galaxies over the next 10 years, launched by Stephen Hawking and science philanthropist Yuri Milner. Building upon our knowledge from stromatolites that life is tenacious and evolved on Earth as soon as it cooled and our knowledge from the Kepler satellite that one in five stars of our galaxy hosts a planet with earthlike conditions, the Breakthrough Initiatives will expand the scope of detecting evidence of extraterrestrial intelligence beyond that of the present SETI Institute.

The only way we can detect distant intelligence is by detecting its technology, Siemion pointed out. The classical example of this from planet Earth has been a telecast of "I Love Lucy." Siemion conceded that the Green Bank telescope and two others that the Initiatives will begin with will not be able to do this, but when a new square kilometer array comes online, it would be sensitive enough to detect the equivalent from a nearby star. He also cited irregular signals from KIC8462852 that suggest that it hosts a very irregular object.

Douglas Vakoch of METI (Messaging ExtraTerrestrial Intelligence) International in San Francisco reported on what he feels is a necessary next stage after 55 years of listening for extraterrestrial intelligence – sending messages. Vakoch advocated sending them repeatedly in all directions, but he also expressed concern that an alien civilization might have achieved an understanding of the universe different from our own, which he considered to be analogous to climbing a different side of a mountain or a different mountain than we have. He added that he would like to see the United Nations involved in this, but he noted that they have higher priority for guarding against errant asteroids.

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

24-27 Jan 2017. Future of Education Technology Conference, Orlando, FL. Visit <www.fetc.org>.

8-11 Jul 2017. 21st World Multi-Conference on Systemics, Cybernetics, and Informatics, Orlando, FL. Visit <http://www.2017iiissconf.org/wmsci>.

Criteria for Inclusive STEM High Schools Identified

NSF-funded research by George Washington University, George Mason University, and SRI International has identified 14 critical components that characterize Inclusive STEM High Schools (ISHSs) as the result of an in-depth qualitative case study of eight exemplar ISHSs. Their research team developed a STEM Inventory based upon these 14 critical components that a school can use to improve its STEM education program. The STEM Inventory can provide an overview of the STEM opportunities offered to students and suggest areas for growth and improvement. The STEM Inventory checklist is available online at <https://ospri.research.gwu.edu/stem-inventory>. The 14 critical components are as follows:

1. A college-prep, STEM-focused curriculum for all. There are rigorous courses in all four STEM areas, or engineering and technology are explicitly and intentionally integrated into STEM subjects and non-STEM subjects in preparation for college.

2. Reform instructional strategies and project-based learning. STEM classes emphasize instructional practices/strategies informed by research on active teaching and learning and immersing students in STEM content, processes, habits of mind, and skills. Opportunities for project-based learning and student production are encouraged, during and beyond the school day. Students are productive and active in STEM learning, as measured by performance-based assessment practices that have an authentic fit with STEM disciplines.

3. Integrated, innovative technology use. Technology connects students, teachers, and mentors with information systems, models, databases, STEM research, and social networking resources for STEM ideas during and outside the school day. The school's structure and use of technology has the potential to change relationships among students, teachers, and knowledge and flatten hierarchies.

4. STEM-rich, informal experiences. Learning opportunities are not bounded, but ubiquitous. Learning spills into areas regarded as "informal STEM education" and includes apprenticeships, mentoring, social networking, and doing STEM in locations off of the school site, in the community, museums and STEM centers, and business and industry. As a result, the relationship among students, teachers, and knowledge changes, and hierarchies flatten to "*…substantially alter the traditional roles of learners, teachers, and instructional resources in the learning environment.*"

5. Connections with business, industry, and the world of work. The school boundaries extend beyond the larger school community by creating partnerships with business and industry. The school environment intentionally reflects the workplace whereby students have the opportunity to think like STEM and non-STEM professionals through internships, mentorships, projects, and other work related activities. Students also have the opportunity to interact with industry professionals and present their work in professional venues. Students connect to business/industry/world of work via mentorships, internships, or projects that occur within or outside the normal school day/year.

6. College-level coursework. The school schedule is flexible and designed to provide opportunities for students to take classes at institutions of higher education or online.

7. Well-prepared STEM teachers and professionalized teaching staff. Teachers are qualified and have advanced STEM content knowledge and/or practical experience in STEM careers. The school has opportunities for in-house professional development, collaboration, and interactions with STEM professionals.

8. An inclusive STEM mission. The school's stated goals are to prepare students for STEM, with emphasis on recruiting students from underrepresented groups.

9. A flexible and autonomous administration. The organizational structure of the school is mission-driven. School leaders have a well-defined strategy for STEM instruction and it is implemented with fidelity within all aspects of school administration. The school may have partnerships with charter networks, non-governmental organizations, or the business community, and these partners work with the ISHS to develop shared goals as well as to provide leverage, expertise, leadership, and resources to the school, supporting it as a long-term partner. In this sense, the ISHS's administrative structure exhibits an external awareness to the community outside the school that promotes a bias towards innovation and action, while also increasing the collective capacity of the school.

10. Supports for underrepresented students. Supports such as bridge programs, tutoring programs, an extended school day, an extended school year, or looping exist to strengthen student transitions to STEM careers. Such supports result in altered, improved opportunity structures, *i.e.*, students are positioned for STEM college majors, careers, and jobs; and student social structures and identities change to accommodate new opportunity structures.

11. Dynamic assessment systems for continuous improvement. The school community supports continuous improvement through data systems. Teachers use summative assessments (*e.g.*, mastery based learning) to inform future instruction and to enhance student learning. School leaders and teachers examine standardized and summa-

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A Decade after *The Gathering Storm*

One of the cover stories in our Fall 2005 issue was a report about *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, a response to the charge to prioritize steps "to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century." Five years later we reported on *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, which assessed what had been done in the intervening five years and found the situation even more dire, largely due to economic conditions which had limited funding for the recommendations of the original report.

Now, more than a decade after publication of *Rising Above the Gathering Storm*, David Kramer has interviewed some of its authors in the November 2016 issue of *Physics Today*. He quotes the chair, retired Lockheed Martin CEO Norman Augustine, as saying, "In my view, the federal government has had a few bright spots, but the federal story is clearly one of deterioration." Augustine especially shows concern that "We didn't foresee that states would disinvest from higher education as they have, particularly in the sciences and engineering. The idea was to get more scientists and engineers. What [the nation has] done is having exactly the opposite effect." Augustine's response to concern about underemployed scientists is not that there is a surplus of them but rather that there is "too little funding for science and therefore not enough jobs for scientists."

Kramer writes about how private funds have been attracted to meet the recommendations of *Rising Above the Gathering Storm*, particularly the training of 10,000 STEM teachers each year for the decade ending in 2021. Change the Equation, an organization of the CEOs of 33 companies, devotes $750 million and employee volunteer hours each of these years. Math for America, which began its efforts to improve the qualifications of math teachers in New York City, has expanded them to other cities as well. And, with $125 million from Exxon Mobil and additional support from others, the National Math and Science Initiative has broadened student participation and performance in Advanced Placement and International Baccalaureate programs. According to Augustine, "We do something I find offensive but it works: we pay students to take an AP test and pass it, and we also pay their teachers."

Another author of *Rising Above the Gathering Storm* interviewed by Kramer is former Energy Secretary Steven Chu, who delights in seeing an increased number of physics majors, which he attributes to millennials' interest in the risks of climate change, clean energy, and sustainability. Expressing more optimism than Augustine, though guardedly, he feels "that the Category 5 has not yet landed on shore. However, the rising storm has not dissipated, but appears to be stalled nearby."

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Inclusive STEM High Schools

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tive assessment data to inform teaching strategies, student supports, professional development opportunities, and resource allocation. Teachers monitor students' progress through online data management systems, and allow supports as needed, or offer additional learning opportunities. Data are available to students and parents.

12. Innovative and responsive leadership. The school leadership is proactive and continuously addresses the needs of teachers, students, and the greater community through innovative solutions, open communication, and uplifting leadership. Leadership is distributed formally and informally, among administrators and teachers creating a flattened hierarchy to manage a complex school environment. Teachers are professionalized and have some autonomy over the curriculum and instruction in the classroom. In this sense, the school leadership is characterized by flat, organic leadership structures and attends to the needs and functions of the school.

13. A positive school community and culture of high expectations for all. ISHSs have a school environment where students and staff feel a sense of personal, intellectual, and socio-emotional safety. Students are required to take rigorous courses in STEM and become well-equipped for higher education. Students understand that it is acceptable to make mistakes in the learning process and are encouraged to take intellectual risks. Teachers are also encouraged to collaborate and take risks in innovative instructional practices. The school environment is personally safe (*e.g.*, free from bullying), and fosters the development of personal identities and interests within a STEM context.

14. Agency and choice. Students choose to attend a STEM-focused high school and understand the challenges that will be involved and develop a sense of purpose coherent with the school mission, committed to a different approach to high school due to its STEM focus. Students have the agency that follows from having choices about the school that they attend; and multiple opportunities to make more choices about STEM academic opportunities, accompanied by increasing personal agency and responsibility outside of school. The emphasis on agency and choice broadens students' sense of belonging in the STEM community and the scope of possibilities.

Farley Describes Hudson Estuary

Kevin Farley, Professor of Civil and Environmental Engineering and the Director of the Institute in Water Pollution Control at Manhattan College in Riverdale, New York, spoke to the Physics Club of New York about "Water Quality and Sustainability of the Hudson River Estuary" at the College on Friday, 16 September 2016. Estuaries serve as a transition zone between inland fresh water and the sea, he pointed out. The Hudson River estuary, which consists of the Hudson River south of Albany, has gone through development, abuse, and recovery in the past 200 years, he added.

His talk based on a chapter of the same title he wrote for Satinder Ahuja (ed.), *Comprehensive Water Quality and Purification* (Elsevier, 2014), focused on four points: 1) unique properties of the estuary, 2) the effect of human development, 3) current challenges, and 4) questions to be addressed.

Unique Properties. The Hudson River begins in the Adirondacks, Farley began, and collects the Mohawk River north of Albany. Glaciers have left many cliffs and steep banks, with interspersed marsh areas. The flow of the river is generally highest in the spring, lowest in the summer. Tides are felt all the way up to Albany, sometimes greater there because of channel narrowing. Denser salt water flows in from the sea in the depths, while fresh water flows out at surface level. Salt water is found as far north as West Point at times of low freshwater flow, but it is limited to the New York City region during high flow. Estuaries are rich in the nutrients they trap, and tides flush nutrients into marsh areas.

Effects of Human Development. The population of New York City multiplied by 100 in 200 years – from 80,000 in 1800 to 8,000,000 in 2000. A major factor abetting this increase was the 1825 completion of the Eric Canal, which transformed the City into a leading center of commerce. Because the Hudson River near the City is too brackish to drink, the Croton water supply system was developed in 1837 to accommodate the City's increasing population, followed by the Catskill water supply system in 1907. Farley emphasized that water supply is the most important part of infrastructure.

The switch of land use from forest to agriculture increased suspended settlement in the river by the 1870s, but there is only about half as much today. Channels must be dredged in New York harbor every few years in order to accommodate the ever larger ships that use it.

New York City uses and disposes 1.1 million gallons of water every day. Only since 1985 has all of it received secondary treatment. The 1972 Clean Water Act has reduced the concentration of fecal coliform (a pollution indicator) by a factor of 100. Dissolved oxygen has also increased since 1972. Because rainfall and sewage are collected in a combined system, diverters are activated after heavy rainfalls in order to avoid overloading the system. Recent efforts have been made to store the overflow and release it for treatment in subsequent dry periods, also to reduce runoff. Nitrogen has become an excessive nutrient, but light limitedness has restricted algal growth, and five sewage treatment plants have enhanced their ability to remove it.

Current Challenges. Today's biggest concerns are the toxic contaminants in the river, the five chief ones being PCBs, PAHs, dioxins, pesticides, and mercury, with PCBs (PolyChlorinated Biphenyls) being chief among those five. The editor of this *Newsletter* wrote an article about their being dumped into the Hudson River by General Electric in the 1985 Supplement on "Water," with follow-ups in the "Clearinghouse Update" columns of our Winter 1990 and 1991 issue, plus almost every issue between 1996 and 2002, the year the US Environmental Protection Agency (USEPA) mandated removal of approximately two million square feet of PCB-contaminated sediment. Farley indicated that subsequent modeling indicates that this action plus natural attenuation will "significantly reduce" PCB concentration in sediment and freshwater fish in the coming decades. This modeling, as he explained it, charts and relates flow, sediment, chemical loads, organic carbon and nutrients, and species in air, water, and the underlying bed in order to project needs for the future. In addition to the removal of PCB-contaminated sediment mandated by the USEPA, Farley said that most dredging from New York harbor must be disposed of on land, because it is too contaminated for ocean dumping.

Questions to be Addressed. Farley concluded his talk with three questions which will affect the Hudson River estuary:

1. What will be the effects of the Upper Hudson Dredging Project?
2. What will be the effect of climate change?
3. Can the estuary support a sustainable ecosystem? (The goal is not to restore the Hudson to what it was but to make it sustainable.)

National Park Centennial

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winning series of novels. In *Rock Bottom* (Minotaur Books, ISBN 978-0-312-68659-9), Em is involved in a private month-long rafting trip in the Grand Canyon that includes a murder. This work allowed Andrews to highlight the work of the NPS in the Grand Canyon. It is fitting to end this contribution by quoting from her acknowledgments: "Most of all, I thank all of us, the citizens of these United States, who have set aside the wilderness of the Grand Canyon under the protection of the National Park Service, so that all who visit may be inspired, each in his or her own way, by its majesty."

The National Park Service Celebrates Its Centennial

by Michael J. Passow, Earth Sciences Correspondent

The National Park Service (NPS) turned 100 years old on 25 August and continues to celebrate its centennial in many ways that you can use in your classroom.

The NPS was created by an Act signed by President Woodrow Wilson. The first national park, Yellowstone, was established in 1872 during the Grant Administration. The current NPS administers 413 areas covering more than 84 million acres in every state, the District of Columbia, American Samoa, Guam, Puerto Rico, and the US Virgin Islands. An annotated timeline is available at <https://www.nps.gov/parkhistory/hisnps/NPSHistory/timeline_annotated.htm>.

In addition to the 59 National Parks, the NPS administers national monuments, battlefields, historic sites, recreation areas, seashores, lakeshores, rivers, and other designated areas. A complete list that may help you identify nearby locations is available at <https://www.nps.gov/aboutus/upload/Site-Designations-08-24-16.pdf>. The largest unit is the Wrangell-St. Elias National Park and Preserve, AK, at 13.2 million acres. The smallest is Thaddeus Kosciuszko National Memorial, PA, at 0.02 acres. Last year, there were more than 307 million visits to NPS facilities.

The NPS arrowhead emblem was authorized in 1951. The sequoia tree and buffalo represent vegetation and wildlife, the mountains and water represent scenic and recreational values, and the arrowhead itself represents historical and archeological values. You can learn more about this symbol at <https://www.nps.gov/glac/learn/news/history-of-the-nps-arrowhead.htm>.

The National Parks can be considered "America's Largest Classroom," and the NPS provides a wide range of educational resources at <https://www.nps.gov/teachers/index.htm>. You can search for suitable activities for your students from a menu that includes science, math, social studies, literacy, and language arts. These are also organized by grade levels ranging from Pre-K to Adult Education.

Educators working with staff at some park facilities have created activities that may provide inspiration for what you can do locally with your students. One example is the "Climate Science in Focus Field Trip" created for Devils Postpile National Monument in California (https://www.nps.gov/teachers/classrooms/climate-science-in-focus-field-trip.htm). Their suite of "Exploring Climate Science" lessons examines Climate Change (https://www.nps.gov/teachers/classrooms/exploring-climate-science-climate-change.htm); Earth as a System (https://www.nps.gov/teachers/classrooms/climate-science-in-focus-earth-as-a-system.htm); and Research Projects (https://www.nps.gov/teachers/classrooms/exploring-climate-science-research-projects.htm). They also have resources devoted to "Climate Science in Focus: Data and Tools" (https://www.nps.gov/teachers/classrooms/climate-science-in-focus-data-and-tools.htm). The Great Sand Dunes National Park and Preserve in CO has developed another set of educational resources focused on "Flowing Waters" (https://www.nps.gov/teachers/classrooms/flowing-waters.htm).

The NPS partners with the Geological Society of America (GSA) and Environmental Stewards to run its "Geologist in the Park" (GIP) program (http://rock.geosociety.org/g_corps/index_gip.htm). The GIP program matches college students and recent graduates age 18 – 35 with short-term, paid internships at NPS facilities. The interns assist with research, synthesis of scientific literature, geologic mapping, GIS analysis, site evaluations, resource inventories and monitoring, and other programs. They help educate park staff and visitors during positions lasting from three to twelve months.

Several sessions at the recent GSA Annual Meeting in Denver highlighted the history and current research conducted in NPS facilities. The "Centennial Celebration of Geology and Hydrology in the National Parks included a poster session (https://gsa.confex.com/gsa/2016AM/webprogram/Session41384.html) and an oral session (https://gsa.confex.com/gsa/2016AM/webprogram/Session40256.html). The Keynote Speaker in the latter was geologist and author Sarah Andrews, recipient of this year's GSA Presidential Medal. Her talk (https://gsa.confex.com/gsa/2016AM/webprogram/Paper276867.html) focused on Edwin D. McKee, longtime Chief Naturalist at the Grand Canyon National Park and a sterling example of everything that NPS staff can be. He was also her mentor early in her career with the U.S. Geological Survey in Denver.

> "Most of all, I thank all of us, the citizens of these United States, who have set aside the wilderness of the Grand Canyon under the protection of the National Park Service, so that all who visit may be inspired, each in his or her own way, by its majesty."
>
> -Sarah Andrews

Sarah Andrews is also the author of *Rock Bottom*, her 2012 mystery featuring Em Hansen, the forensic geologist who is the central character in her award-

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Gershenfeld

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feld sought to foretell the ultimate uses of personal fabricators by setting up the first Fab Labs – with a laser cutter, a sign cutter, a 3-D milling machine, and tools for programming microcontrollers (in effect, a Programmed Materials Processor) – in India, Costa Rica, Norway, Ghana, and inner-city Boston, at a cost of $20 thousand each. The response to these Fab Labs was the same as that originally experienced at MIT. Gershenfeld observes that while PCs have enabled anyone to develop software and laser and inkjet printers have enabled anyone to be a printer, big companies are still needed to do the big things. This also applies to mass-produced goods, he adds. But "the emerging personal fabrication tools . . . are intended for personal rather than mass production," (p. 16) he adds. "*Fab* tells the stories of pioneering personal fabrication users, and the tools they're using." (p. 17)

Gershenfeld has written *Fab* in sets of paired chapters, one to discuss ideas, the other to tell stories of people implementing them, among them Alan Alda, Frank Gehry, and Seymour Pappert. The focus of the second set of paired chapters is "The Past." He goes back to the development of humanism in the Renaissance, which emphasized seven "liberal arts" (so named because they were "liberating") – geometry, arithmetic, astronomy, music, grammar, logic, and rhetoric. Aside from painting and sculpture, the process of making something – typically for economic gain – was relegated to the "illiberal arts." Those so employed became the working class of the Industrial Revolution. But, Gershenfeld points out, in doing so, they lost their role as fabricators – this, he says, was now taken over by engineers, who designed the machines and how they were used.

Meanwhile, the process of automation began with Joseph-Marie Jacquard's use of punched cards to program a loom, Charles Babbage's realization that these cards could be used to program a steam-powered engine to perform mathematical operations, and Herman Hollerith's use of these cards to tabulate the 1890 census (his company became IBM in 1924). The idea for the modern computer came from Alan Turing, but it fell to the U.S. Army to fund building it – the 1946 ENIAC (Electronic Numerical Integrator And Computer), which John von Neumann co-opted to do calculations for nuclear weapons design. Gershenfeld suggests that getting von Neumann "interested in computers was perhaps ENIAC's most important consequence." (p. 38) Von Neumann went on to propose the 1952 EDVAC (Electronic Discrete Variable Computer) and to consider "what might happen if computers could manipulate the physical world outside them with the same agility as the digital world inside of them." (p. 39) He also recognized that such a computer would have the property of self-reproduction: "The computer could direct the constructor to copy both of them, including the program for the copy to make yet another copy of itself." (p. 39)

Gershenfeld goes on to note that the "first general-purpose programmable fabricator" was the Whirlwind computer developed at MIT and demonstrated in 1951. Computer-aided manufacturing (CAM) was not far behind, but design awaited the TX-2 (also at MIT), for which Claude Shannon's student Ivan Sutherland developed Sketchpad (1960). Gershenfeld laments that

> literacy has . . . regressed . . . to the most minimal meaning of reading and writing words, rather than grown to encompass the expressive tools that have come along since the Renaissance. We're still living with the historical division of the liberal from the illiberal arts, with the belief that the only reasons to study fabrication are for pure art or profane commerce rather than as a fundamental aspect of personal liberation. (pp. 41-42)

"Consider what would happen if the physical world outside computers were as malleable as the digital world inside computers," he adds (p. 42).

The next section of *Fab*, focused on "The Present," consists of seven pairs of chapters, each focused on one type of technology:

Subtractive Technologies: sign cutters, laser cutters, waterjet cutters, milling machines

Additive Technologies: blow molding, injection molding, 3-D printing

Descriptive Technologies: printing with pixels, printing from points with mathematical equations describing the curves connecting them, extrusion of 2-D shapes to become 3-D, addition, subtraction, and intersectioning of two overlaid 3-D shapes, use of Finite Element Analysis to test the effect on a design of "forces, vibration, heat, airflow, fluid flow, and electric and magnetic fields." (p. 128)

Computation Technologies: microcontrollers

Instrumentation Technologies: sensors

Communications Technologies: ASCII code, Internet Protocol, and Internet 0, in which messages are sent in ASCII code

Interaction Technologies: Digital lighting displays, digital printing, and digital-to-analog sound

The interesting stories Gershenfeld tells along with these chapter pairs include how Seymour Pappert happened to develop LOGO – because Marvin Minsky had

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mistaken the day he was to meet Pappert and this left Pappert alone in Minsky's office with an unused PDP-1. "There's very little difference in the technology for serious work and serious play," writes Gershenfeld. (p. 144) But perhaps the most interesting stories are those that take place in India. The Fab Lab at Vigyan Ashram enabled local people to develop devices to measure the quality of milk and rice at the local market. And elsewhere in India reverse engineering of satellite dishes enabled a network of cable TV providers to bring cable TV to parts of India before telephone or electricity was available (they used car batteries).

In his final pair of chapters, focused on "The Future," Gershenfeld recalls some more of the past. He recalls that as a student at MIT, Claude Shannon sought an alternative to the unwieldy Differential Analyzer, the analog computer of Vannevar Bush, MIT's Dean of Engineering and Shannon's advisor, and that Shannon found his answer in discovering that for digital communication there was a noise threshold below which there were no errors. He also recalls a 1945 essay in which Bush envisioned "that computing machines might eventually manipulate ideas with the same dexterity that mechanical machines could manipulate materials" (p. 234) and adds that "the key to the creation of information processing machines proved to be the application of Shannon's ideas about communication to computation." (p. 234)

Gershenfeld also returns to one of the opening themes in his book when he notes that at his death John von Neumann was working on the "Theory of Self-Reproducing Automata," which Gershenfeld sees the basis for in biology: "The very close analogy between the role of digitization in reliable communications and computation and its role in fabrication in the ribosome suggests a corresponding analogy between the prior revolutions in digital communications and computation and a revolution to come in digital fabrication." (p. 241)

Gershenfeld then concludes by voicing his speculations about the future, much of which he has already expressed at the beginning of his book. Just as "the real impact of digital communications and computation came in giving ordinary people control over the information in their lives," he writes, "digital fabrication will likewise give individuals control over their physical world by allowing them to personally program its construction." (p. 241) Moreover, the detail of control humans will have over the things they design and make will be microscopic – down to the last atom and molecule. (And we will similarly be able to disassemble these things as well, in order to insure complete recycling.)

In response to arguments that digital fabrication, in addition to robotics, genetic engineering, and biotechnology, poses a threat to the future of civilization, Gershenfeld counters that thus far we have been able to develop sufficient countermeasures to keep from being destroyed by firearms, nuclear weapons, computer viruses, and a real virus, HIV ("hard to believe that we could accidentally or intentionally come up with a self-reproducing machine even more effective" (p. 248)). "Bad guys are already impressively effective at acquiring the best available technology for the destruction of their enemies; fab labs are likely to have a far greater impact on the stability of the planet by helping everyone else acquire the technology they need for their survival." (p. 244)

The Fab Labs described by Gershenfeld are maker spaces of the highest level, and the summer AAPT meeting also had an entire session devoted to them. I had attended a talk the day before Gershenfeld spoke – by Wouder Deconinck of the College of William and Mary, who reported that when the College solicited input for preparing physics majors for careers outside academia, the responses included design and leadership. As a results, they designed their Small Hall Makerspace to encourage failure to further innovation and prototyping over solutions. The space includes a rapid prototyping and electronics shop, a student machine shop, and a laser cutter (like Gershenfeld, they also found it more useful than a 3-D printer). It was built in a no-longer-needed computer lab. Other interested departments have contributed to it, and faculty have used it as well (especially the 3-D printer and laser cutter). Students have been given a voice in the purchase of new equipment and management of the space. The public is also invited to participate in its Open Build Events. Proposals are funded (with user board approval) up to $500 ($1000 if it is interdisciplinary). Use of the space has been integrated into several courses. Students are more likely to embark on a career doing something like what they do in a makerspace than in solving a homework problem, Deconinck said.

A weblink to past issues of the Teachers Clearinghouse *Newsletter* has been established on the Modeling website:

Visit
<http://modeling.asu.edu/modeling/weblinks.html>
And select the section
<Real-world applications, engineering>.

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Jordan Ellenberg, *How Not to be Wrong: the Power of Mathematical Thinking* (Penguin, New York, 2014). 468 pp. $27.95. ISBN 978-1-59420-522-4.

How not to be wrong? Don't guess. Do the math. "Math is a science of not being wrong about things," Ellenberg writes on p. 2. "Mathematics is the study of things that come out a certain way because there is no other way they could possibly be," he adds ten pages later. And on the following page, "Without the rigorous structure that math provides, common sense can lead you astray. . . . But formal mathematics without common sense . . . would be just a sterile exercise. . . ."

Ellenberg divides math between the profound and shallow on the vertical axis and between simple and complicated along the horizontal axis and tells his readers that his book will concentrate on the upper left quadrant – profound and simple. In this way he sets his audience as the lay reader, but the more mathematical background a reader has, the more she or he will be able to appreciate this book.

Ellenberg groups his chapters to focus on five aspects of mathematics: linearity ("Nonlinear thinking means *which way you should go depends on where you already are*." (p. 24)); inference (the criterion that one can infer a significant effect was set at $p = 0.05$ by R. A. Fisher, who developed the p-value as the probability of that effect if the null hypothesis (that there is no effect) is true); expectation (any activity has a risk of negative consequences, but avoiding them also has a cost, and one must weigh this cost against the benefit of avoiding the negative consequences); regression (if two variables are correlated, either one could cause the other, both could have the same common cause, or there could be no causal relationship at all); and existence (it is difficult to get majority support when there are three choices).

In order to make his book interesting to lay readers, Ellenberg draws many of his examples from everyday life and the work of actual mathematicians (and tells some interesting stories about them along the way). It is particularly interesting how Ellenberg makes frequent subsequent references to mathematicians he has introduced earlier in the book, as if they are a cast of characters in a novel that he has plotted in the course of his writing.

One of the things that particularly interested me is what Ellenberg had to say about the Fisher criterion of $p < 0.05$ for statistical significance. This means that, on average, one experiment in 20 will give a statistically significant result, even if there is none. Because of this, Ellenberg warns that rather than take this to be a statistically significant result, it should be taken as a clue that the effect should be studied further. The "boiler plate" call for further research at the end of a paper should therefore be *heeded*, because only replications of an experiment can show whether a statistically significant result is a one in 20 fluke or a result that, in the words of Fisher, "rarely fails to give this level of significance." (p. 160) Unfortunately, replications that confirm earlier results and experiments that show no statistical significance are not attractive to publishers, though the latter could provide the 19 out of 20 trials of an experiment that showed a one in 20 false positive. Ellenberg faults publishing in this regard (p. 152) but notes some encouraging indicators of change (pp. 161-162). (Jennifer Couzin-Frankel, *Science*, **337**, 1031 (31 Aug 12) notes Elizabeth Iorns's Reproducibility Initiative, a clearinghouse to find a replicator, whose replication (funded by the applicant) would be published in *PLoS ONE*.)

Another topic Ellenberg devotes considerable attention to is the mathematics of gambling, describing how three organized groups of players saw a way to profit from Cash WinFall in Massachusetts. But because of all the work they had to do, Ellenberg opines that "if gambling is exciting, you're doing it wrong." (p. 230) Whether it be lottery tickets or another type of investment, Ellenberg counsels that it is unwise to risk money that cannot afford to be lost. Thus wealthy people are better able to afford riskier investments. On the other hand, he concedes that a single powerball ticket is an affordable risk. Although it is mathematically unwise, this negative is outweighed in utility by the pleasure it brings. To reverse the adage on p. 230, it may be "wrong," but it is "exciting."

Ellenberg also writes very insightfully about correlation between two variables, which he dates back to Francis Galton (of eugenics notoriety), who plotted the heights of sons versus the height of their fathers on a scattergraph. He found the points clustered in an ellipse, whose major axis was the best fit straight line. To see that the eccentricity of this ellipse corresponds to today's concept of correlation, note that had there been complete correlation, the points would have lain on a straight line (eccentricity 1), and had there been no correlation at all, the points would have been distributed in a circle (eccentricity 0). Today, of course, we use the Pearson correlation coefficient, which Ellenberg gives an amazingly straightforward way to understand: if there are two data sets of n numbers, express each one as a vector in n-dimensional space from a common origin found by subtracting the mean of the numbers from each one. The

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Pearson correlation is the cosine of the angle between these two vectors, as determined from their inner (dot) product.

Because many of the mathematical examples from everyday life involve predicting the future, the techniques of probability theory, of which Ellenberg attributes the origin to the correspondence between Fermat and Pascal, must be applied. Ellenberg recalls one summer during his college years that he worked for a researcher in public health, who assigned him the job to determine from a big folder of papers how many people would have tuberculosis in 2050. Although he was unable to give his boss a justifiable number, because of all the uncertainties involved, he notes that "math gives us a way of being unsure in a principled way . . . 'I'm not sure, this is why I'm not sure, and this is roughly how not-sure I am.'" (p. 420) He notes that it was in calculated probabilities that Nate Silver voiced his statements about how President Obama would fare in each state in the 2012 election.

- John L. Roeder

Kathryn Schulz, *Being Wrong: Adventures in the Margins of Error* (Harper Collins, New York, 2010). viii + 405 pp. ISBN 978-0061176043.

Being Wrong is a book all educators and science teachers need to read. It is a comprehensive analysis of the all too familiar situation we occasionally discover we are in. If it was that I was wrong; could I admit it? And as soon as I realized it, I denied it, and would never revisit it. So I act as if it never occurred. That is why we all need read this insightful book. It explores and explodes ideas about error. If this seems necessary and very familiar it is because the knowledge of being wrong IS a universal human experience. We need to know what this author has to share.

Recently I spent three days in Albany grading practice forms for the State Education Department. Small groups try to distinguish whether a particular student response is completely wrong, partially wrong, or to grant full credit. Grading in conversation discussing the differing student responses, each varied attempt to answer the question has helped me tease apart error from answer. Seeing what is there, point by point, talking aloud and to myself, if to grant a point, going over the answers offered; discerning how each question functioned in situ, testing the test; evaluating responses, and choosing examples of answers that actual graders could employ to grade in a uniform and standard way. Being involved in this task years ago, I became aware of just what it was I needed to teach; how to best present ideas in a lesson and also target questions to challenge student accomplishments most productively with a question, quiz or test. Actual authentic assessments! Not just "teaching to the test" but improving my practice – to clarify, to teach, to address major misunderstandings, and to develop concepts to uncover student growth. I wanted all to "understand the patterns of physics" to be most effective in my role. So early on in my teaching career I became keenly aware as to how students' preconceived notions, half understood concepts, and outright errors were all part of the process of learning. Now I wish I had had this book then to help with these goals. So I offer this review of a book which can be a useful tool. What it has to offer is helpful for all science educators.

Reviewing how we go from sure to unsure, from formerly certain I am right to not so sure and then I was previously wrong is an education unto itself. The psychology of how we cover over our tracks and then refuse to admit what we formerly believed is fascinating. *Being Wrong* is a masterful tour of error in the real world. What this book is all about is the many ways we can be wrong. Wise, witty, illuminating, philosophical, psychological, and surprising; it is well researched and scholarly in its treatment of all the things we can be wrong about. An exploration of the many modes of smug correctness which get upended when we discover the error of our ways; a well written journey from "I told you so" to mistakes were made. In her way the author suggests in an introduction a positive view of error, why it is needed and inevitable; the strong case is made for human fallibility as proof of our real existence. When Moliere observed that "it infuriates me to be wrong when I know I'm right," he said much about the thought patterns of wrongness. Why is it so hard to say "I was wrong?" Maybe being wrong can be too closely associated with stupidity, shame, mental failure or worse. But it was Socrates who first observed that error is only seen in comparison to true knowledge. We need error to know truth! The Maxwell-Boltzman distribution, what we know as the familiar normal curve, was first used by Laplace to establish from many observations the best result statistically. Laplace would zero in upon the best result using the many somewhat erroneous observations and average out all the errors of each astronomical observation. He used mistaken observations to point out the best result. Error analysis was employed to highlight the best results. Similarly, when our dreams and fears actually and seemingly real, perceived within a nightmare, highlight deeper, hidden psychological concerns, our mystery existence can be revealed. This book revisits the Greek myths, the Shakespearean drama, and can awaken the powerful myths of the mysterious journey called life. If only error could be eliminated in all human affairs. Or is it that error is normal and natural to the behavior and process of our senses and our minds?

Can the scientific method save us from all misperceptions, doubts, and false beliefs? Not likely. Is it that we

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can be sure and convinced but truly wrong in our conclusions from incomplete and scant evidence? To err is human and to forgive a touch of the divine. *Being Wrong* reveals to the reader how our preconceived notions about crime and punishment, sensibility and sense perceptions, love and a change of heart; and self-awareness and self-deception from among many things make us wholly unable to actually face facts realistically. How we repeatedly and so stubbornly choose the irrational over the reasonable; trusting in our senses yet knowing they are not so sensible. Innately error prone, humans need to learn the lesson of embracing incorrectness if we are to grow towards a more honest, accurate and true existence. Timely and relevant during today's perfect storm of human folly; think political posing and musing, energy choices, to climate change or to non-anthropogenic climate change, differing diets and less knowable health claims, free and not so free markets, best investments and better prices and many, many others, we need put useful perspective to our sureness in our wrongness. As was said in another book I am reading, "we need to be tolerant of the intolerant"! *Being Wrong* is an amazing comprehensive and detailed 339 pages with extensive notes, 15 chapters on all forms of mistakenness; on the senses, on knowledge, on beliefs, on crime, on evidence, on politics and on society, on being sure and not so sure, on denial, on the various degrees of wrongness, on love and divorce, on transformation and coming to the real truth; and finally upon the optimistic meta-induction we all engage in from the history of everything. You best would know this as "I think therefore I am." Or so we think as we are. How we make up most of what we seem to know from the belief that we actually know something. Like the fact that the sun rises in the east. Is that actually true every day and everywhere? After reading this book I feel the best that I can say is what Socrates was said to have said. "All I know is that I know nothing." But you should know this book is a very interesting book you can really benefit from reading it. Well worth it if I am not wrong.

- Jack DePalma

(*Editor's Note*: Jack DePalma is a retired New York City Department of Education physics teacher and the President of the Physics Club of New York.)

George Musser, *Spooky Action at a Distance: the Phenomenon that Re-imagines Space and Time and What It Means for Black Holes, the Big Bang and Theories of Everything* (Scientific American/Farrar, Strauss and Giroux, New York, 2015).

I have wanted to read a book such as this for a very long time. So when in the elevator I mentioned such to a neighbor, her comment that "It's about time" caused me to immediately offer the statement "No – It's about space!"

Spooky Action at a Distance is the very readable journey through the intricacies of quantum weirdness, observer-created reality, and the seemingly non-random characteristics observed for correlated but distant particles as presented in modern quantum theory. Like Schrödinger's Cat and the Einstein, Podolsky, Rosen effect, this book should make many of the surprises and twists of modern Quantum Theory into understandable and hopefully not-so-unbelievable physics. Not really distant spooky action but actually observable effects of global factors of spacetime in General Relativity and Quantum Field Theory. This book presents recent theoretical improvements suggested about the strange assumptions of quantum mechanics studied in our youth, sometimes labeled the Copenhagen Interpretation. The book reveals a deeper level of clarity about space, position, and location that makes quantum reality into actual sense.

I have argued, debated, and discussed topics such as this book presents with friends, colleagues, and students over the past 50 years. Mystical explanations utilizing faster-than-light signals, hidden variables, and possibly incomplete explanations would not jive with the cold evidence. All explanations seemingly rested upon the same shaky ground. No explanations were complete or satisfactory. "Shut up and calculate" was the answer to those who asked why. There were no easy answers to quantum paradoxes and contradictions. "What is an electron?" I asked of a professor at Brooklyn Polytechnic in 1974. "A blip on the screen" was the answer given – no more or less. What was acting – particle or wave? Is the cat in the box alive or dead? Is it actually free will in an undetermined world or predestination within strict mechanical causality? My head still hurts today.

George Musser knows too much of the history and too many of the stories of how these ideas evolved and are so often misunderstood. The book explains how in the very early days of the twentieth century, when the photoelectric effect was first explained by Einstein with Nobel-winning clarity, he fully fathered the concepts but still searched for how relativity and quantum effects were subtly intertwined. He was writing to others in his personal confusion concerning deeply held reservations about the meaning of position, location, and place as the stage set of reality, as the thing-ness spacetime platforms within the all-pervasive ether. And if we could just step outside all spacetime, and look upon all matter energy of the physical universe, before the start till after the end, as Martin Heidegger would have it, to see ALL as if from God's perspective, all there is; before, during, and after; we would not see quantum weirdness as weirdness at all! This is a flaw we must see past. How can we exist beyond spacetime? Einstein struggled as we all do with this. The book offers an insider view of the Solvay Con-

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RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Michael Marder, Tadeusz Poazek, and Scott Tinker, "Physics, Fracking, Fuel, and the Future," *Physics Today*, **69**(7), 46-52 (Jul 16).

After noting how the discovery of oil happened just in time to save whales from being exploited for their oil (and later also to alleviate the need to provide hay for a burgeoning number of animals for transportation), these authors note that impending shortages of oil have been met by increased recovery from fracking to the point that U.S. oil production is now almost as large as it was at the Hubbert peak in 1970. Although they do not discuss the environmental consequences of burning this increased amount of oil, they do call upon physicists to be more involved in dealing with the world's future energy issues, not merely be content to teach it as a "trick for solving problems with roller coasters."

2. Matthew N. Eider, "Cold War computers, California supercars, and the Pursuit of Lithium-Ion Power," *Physics Today*, **69**(9), 30-36 (Sep 16).

Eider traces the origin of the lithium-ion battery, which is one of the enablers of today's electric cars, to John Goodenaugh's developing expertise on spinels while working on an air-defense computer in 1952.

3. Tess Hegedus, Veronica A. Segarra, Tawannah G. Allen, Hillary Wilson, Casey Garr, and Christina Budzinski, "The Art-Science Connection," *Sci. Teach.*, **83**(7), 25-31 (Oct 16).

Biology students from a performing arts high school were mentored through eight biology experiments by undergraduate biology majors at a local college on a Saturday morning, then developed a project in the studio or performing arts inspired by one of the eight biology experiments.

4. Joseph Ochterski and Lisa Lupacchino-Gilson, "Getting an A in STEM," *Sci. Teach.*, **83**(7), 39-45 (Oct 16).

A chemistry teacher and an art teacher collaborated on three interdisciplinary projects in which both their students participated.

5. David H. Richter and Fabice Veron, "Ocean spray: An outsized influence on weather and climate," *Physics Today*, **69**(11), 34-39 (Nov 16); Roger A. Pielke, Sr., Rezaul Mahmood, and Clive McAlpine, "Land's complex role in climate change," *Physics Today*, **69**(11), 40-46 (Nov 16); Heather D. Graven, "The carbon cycle in a changing climate," *Physics Today*, **69**(11), 48-54 (Nov 16).

These three articles in the November 2016 issue of *Physics Today* address the role of three aspects of the Earth system in climate: the exchange of energy and moisture between air and sea, the impact of land use (*e.g.*, urban heat islands), and how the carbon cycle affects the climate and how the climate affects the carbon cycle. The last presents the restrictions on carbon dioxide emissions from fossil fuel combustion and the maximum global temperature rise to achieve a scenario with long-term temperature increase above the pre-industrial level no greater than 2° C, as specified by the 2016 Paris Agreement, according to seven climate models.

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ference of 1927 when Einstein and Bohr wrestled with these ideas – of particle-wave duality both in public and in private. Then at the next Solvay Conference in 1930, a more fundamental but still contentious and unresolved idea surfaced. So who really won the debate? We mostly now accept the Copenhagen Interpretation of quantum weirdness even if it makes little sense. But it was Einstein who was not allowed a final word on this ongoing philosophical debate. The EPR paper presented in 1930 concluded with a section penned by Rosen but in fact Einstein disagreed with his offered conclusion. As there would be no more discussion on the topic; the Second World War precluded any follow up debates among the major players then and after too. And so much then went unsaid which was still so much in need to be understood. That is where I came in; not magic or mystic but confused and confusing.

This book has so much to offer I could never give a full and complete presentation of its merits to those such as myself who are still interested in gaining an accurate sense of why quantum weirdness is potentially just a failure to appreciate spacetime global characteristics. No report I could write could provide how it is seemingly not so weird and not so paradoxical. The mysteries of Quantum Field Theory really are not mysterious at all. But read this book! I am convinced this is the key. That global spacetime and non local spacetime are the many paths to get around quantum weirdness.

- Jack DePalma

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Alberts still crusading for improved science education

Bruce Alberts is no stranger to the pages of this *Newsletter*. As President of the National Academy of Sciences and editor of *Science*, he has relentlessly crusaded for improvement to science education. A recent interview with Jacob Roberts for the publication of the Chemical Heritage Foundation, *Distillations*, shows that Alberts's concerns have changed little from those expressed to the National Science Teachers Association Convention in Philadelphia in 2003, as reported in our Spring 2003 issue.

Then he was reported as distinguishing between knowledge of science words and understanding of science concepts, pointing up the importance of the latter. In his interview with Roberts he said, "Science education has become overloaded with facts that squeeze out all understanding or real joy from the subject."

Rather, science education should be experienced as a scientist does science: "Science education should be about learning to think and solve problems like a scientist – insisting, for all citizens, that statements be evaluated using evidence and logic the way scientists evaluate statements," he told Roberts. And, if people can learn to evaluate scientific claims on the basis of scientific evidence, they will be more likely to evaluate other claims on the basis of evidence.

Alberts elaborated on this theme by honoring his mentor, John A. Moore, whose volumes on "Science as a Way of Knowing" were lovingly reviewed by the late Irma Jarcho in our Winter issues of 1986, 1987, 1988, and 1990 and our issue of Spring 1990. "We want people to understand that science is a way of knowing about the world, and high-school graduates should be able to use some of those approaches in their everyday lives," Alberts stated.

Alberts had some pointed comments to address three other issues related to improving science education: the importance of communicating science to the public; the public's intolerance of the 95% certainty practice of science; and the empowerment of the best teachers. "If you can't communicate to people outside your field, then quite often your science isn't understood by those who need to use it," he said, recalling a suggestion by Nobel Laureate Dudley Herschbach that "in order to get your PhD, you should have to write a two-page introduction to your dissertation that your grandmother could understand."

On the issue of 95% certainty, he had this to say: "Everybody should recognize why scientists say that something is 95% certain and why the public should go along with that consensus. If somebody told you it was 95% certain that your house was going to burn down next year unless you changed your electrical wiring, you'd probably change it."

In addition to empowering our best teachers, Alberts was critical that school districts were too impatient. Apparently alluding to the Next Generation Science Standards, he noted that "we have . . . a vision for how to make real progress over the course of the next 10 years, but school districts . . . try to pretend that they can solve problems and change things in two years." "I'm a big advocate for empowering our best teachers to have a much larger say in policies at all levels," he went on, "all the way from schools and school districts to states and nations. There needs to be a cultural change, but that takes time. I can be patient, but I'm impatient with the fact that a critical part of our population has discounted public schools when they're really the lifeblood of the future for the country. Our nation can't be successful in the future without excellent public schools."