TEACHERS CLEARINGHOUSE
FOR SCIENCE AND SOCIETY EDUCATION
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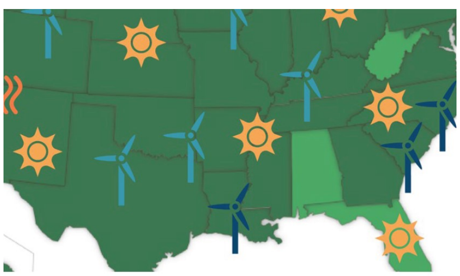
Energy Self-Reliance of States Charted

The Institute for Local Self-Reliance has just published its third edition of *Energy Self-Reliant States 2020*. Authored by Maria McCoy and John Farrell of their staff, it evaluates from data provided by the U.S. Energy Information Administration, U.S. Department of Energy, National Renewable Energy Laboratory, and the U.S. Geological Survey the potential of each of the 50 states to generate various types of renewable energy. They report that "the bottom line is that improved renewable energy technology would allow nearly every state to produce 100 percent of its electricity needs from local renewable resources."



Energy Self-Reliant States 2020
Third Edition

A breakdown of what they found is as follows:

- The potential to generate electrical energy needs from rooftop solar installations ranges from 17% (Wyoming) to 75% (California).
- The potential to generate electrical energy needs from offshore wind ranges from 0% (for inland states) to more than 1000% (Oregon, Maine, Massachusetts, Rhode Island, Louisiana).
- The potential to generate electrical energy needs from onshore wind ranges from 15% (New Jersey) to more than 1000% (states between the Mississippi River and Rocky Mountains).

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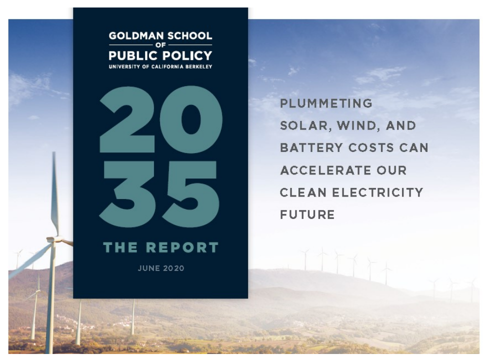
2035 Report Charts 90% Clean Electricity

According to the October 2018 report by the Intergovernmental Panel for Climate Change (IPCC), "Global carbon emissions must be halved by 2030 to limit global warming to 1.5°C and avoid catastrophic climate impacts." Most studies have targeted 2050 as the year the electrical grid can be decarbonized. The *2035 Report: Plummeting Solar, Wind, and Battery Costs can Accelerate our Clean Energy Future* from the Goldman School of Public Policy at the University of California, Berkeley, demonstrates that, with reduced cost of wind and solar, carbon emissions from the U.S. grid can be economically reduced 90% by 2035, as opposed to a 55% reduction from a No New Policy scenario (resulting from choosing the lowest market-based cost of equipment). According to this report, released in June 2020, this would be done with 70% of electricity generated from wind, solar, and battery storage, 20% from hydroelectricity and nuclear, and 10% from natural gas, although no new natural gas plants would be built and all coal-fired plants will be retired. Moreover, this could be achieved at a lower cost per kilowatt-hour, but still cost 12% more than the No New Policy scenario. This cost difference, however, would be more than offset by avoidance of health costs. And by 2035 new technologies should enable increasing the percentage of carbon-emissions-free electrical energy to 100%.



The *2035 Report* used the National Renewable Energy Laboratory (NREL) Regional Energy Deployment System (ReEDS) model and Energy Exemplar's PLEXUS

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Cook challenges attempting the (seemingly) impossible

One should always set goals a bit beyond what they think can be done. Otherwise there won't be any stretch for further growth. Or, as he paraphrased John Stuart Mill, "Students who are never required to do what they cannot do will never know what they can do." This is how David Cook, longtime professor of physics at Lawrence University in Appleton, WI, began his talk on "Attempting the (Seemingly) Impossible" after receiving the Robert A. Millikan Medal from the American Association of Physics Teachers on 22 July 2020.

Cook also cited the Queen in *Alice in Wonderland* who liked to do six impossible things every day before breakfast, Andrew Wiles for his proof of Fermat's last theorem (if you never try, you never succeed), and those who accepted the challenge to land a man on the Moon before 1970. Failing often can lead to success sooner, he said, and the quest for an impossible goal has often led to other noteworthy results.

The Millikan Medal "recognizes those who have made notable and intellectually creative contributions to the teaching of physics," and Cook's achievement, as he described it, was attempting the (seemingly) impossible challenge of building up Lawrence's physics department. He and his departmental colleagues recognized the need to make physics attractive to incoming freshmen. They decided to attempt this with laser physics and computational physics and held weekend workshops on these topics for high school students. It turned out that through these workshops they attracted students not only to physics but also to Lawrence. Lawrence's success was noted and recognized, he added, though not always emulated.

"Attempt the (seemingly) impossible," he concluded. "You may achieve it. Even if you don't, you will achieve something worthwhile."

(*Editor's Note*: Cook's *Computation and Problem Solving in Undergraduate Physics* is downloadable from ComPADRE.)

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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>.

Online Meeting describes Online Physics Education

by John L. Roeder

The summer 2020 meeting of the American Association of Physics Teachers (AAPT), like the meetings of every other professional association, was held online. Although we couldn't be physically together, everything else that was scheduled to happen in Grand Rapids (MI) did happen – but I didn't have to leave my house. AAPT had all the presenters of contributed papers prerecord their talks, and they were mounted on an easy to use platform by Underline, where they could be viewed at my pleasure, although I had to watch a presentation before the time it was originally scheduled for presentation if I wanted to ask the presenter a question at a Q&A session that was held at the originally scheduled presentation time.

The plenaries were livestreamed from wherever the plenary speaker happened to be when they were originally scheduled, and viewers asked their questions via chat, to be relayed to the speaker after the talk by the moderator. All the spaces normally expected at such a professional meeting – for special groups and vendors – became special drop-in spaces. The event that was most spectacular – and also perhaps most spectacularly advantaged – was the Demonstration Show, which is always the highlight of the meeting. Usually, though, the physics demonstrators have to schlepp a lot of equipment across the country for their demonstrations or depend on the host institution to provide it. This year six physics lecture demonstrators were able to perform their demonstrations in *their own* lecture halls as they would for students on campus. They fully coordinated with each other what each would do and passed the floor among each other with terrific aplomb – and we all had a great time!

It was fitting that a prominent feature of an online meeting of a group of physics educators should be how they handled physics labs online the three months preceding the meeting. Of the twenty prerecorded presentations I viewed on this topic, I found a great deal of diversity – no fewer than seven approaches, though some were only slight variations of another.

Some institutions sent their students videos of instructors performing the experiments in such a way that the students could record the measurements made from readings on measuring devices – including Stony Brook, Wake Forest, Michigan State, Clayton State (GA), Western Washington, Vassar, Lawrence, and Wisconsin-River Falls – while yet another, East Carolina, sent students the actual data to analyze.

Some institutions, including Stony Brook, Clayton State (GA), Western Washington, and Bergen Community (NJ), used simulations, usually PhETs.

Some institutions, including East Carolina, Clayton State (GA), Athabasca, Bergen Community (NJ), had students do experiments at home, using equipment available there. A variation on this was to have students do experiments at home, using equipment provided by the school. This is what David Cook said in his Millikan address that Lawrence University did for its advanced lab students (see separate story). Two particular types of apparatus stood out: iOLab (used at Stony Brook, Wake Forest, and Arkansas Tech) and phyphox (used at Livermore H. S. and SUNY Buffalo).

Details about iOLab were provided by Jack Dostal of Wake Forest University. The iOLab connects to a computer via a Bluetooth dongle and contains three wheels with sensors to measure position and velocity, a gyroscope, an accelerometer, a force probe with springs, bumper, eye-bolt, and screwdriver, microphone and speaker, electronics breadboard connections, and a light meter. There is also a secondary accessory pack for additional experiments. Dostal said that the iO mechanics labs are simpler than those Wake Forest assigns in-person, but they can't help students with the Wake Forest labs if they get stuck at home on them. The cost is $185 per unit, plus $45 for a lab manual from Vital Source Bookshelf.

Susan Johnston of Livermore H. S., conveniently down the street from Lawrence Livermore National Laboratory (LLNL), explained that SmartPhones come equipped with the following sensors: a three-axis accelerometer, a three-axis gyroscope, and a three-axis magnetometer, a pressure transducer, microphones and speakers, a GPS system, a hi-res video camera, and a hi-res timer. They are also capable of fast data processing and analysis, hi-res graphical interface with a touch screen, and Bluetooth and Wi-Fi data communication and transfer. Apps therefore allow SmartPhones to become mobile labs, and RWTH Aachen University has made this app called phyphox (physical phone experiments, available at phyphox.org). She explained how she has worked with David Rakestraw at LLNL to develop learning modules using phyphox, which are available at https://st.llnl.gov/sci-ed/distance-learning. Although they are developed for "in-class" courses, they can also be used remotely. Johnson also showed that when you download the phyphox app, you see a list of the raw sensors: Acceleration (w/o g), Acceleration (w/g), Gyroscope, Light, Location (GPS), Magnetometer, and Pressure, also a list of tools: Audio Amplitude, Audio Autocorrelation, Audio Scope, Audio Spctrum, Doppler effect, Frequency history, Sonar, Tone generator, Applause meter, Elevator, (In)elastic collision, Centripetal acceleration, Pendulum, Roll, Spring, Acoustic stopwatch, Motion stopwatch, Proximity stopwatch, Acceleration spectrum.

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The NGSS in College Teaching

Although the Next Generation Science Standards (NGSS) were developed for K-12 science education, their presence has found its way into college physics teaching to the point that the American Association of Physics Teachers (AAPT) devoted a session to them at its summer 2020 meeting ("Exploring the Implementation of NGSS Framework in Undergraduate Science Disciplines").

Three speakers spoke about the 3DL4US (which appears to take its name from "Three Dimensional Learning For the United States) Project, developed jointly by Michigan State University (MSU), Grand Valley State University (GVSU, also in Michigan), Florida International University (FIU), and Kansas State University (KSU). James Laverty of KSU explained how the Project aims to institute in introductory STEM courses at the college level the three dimensional learning (3DL) of the NGSS, in which science and engineering practices (SEPs), cross cutting concepts (CCCs), and disciplinary core ideas (DCIs) are integrated in science teaching. To this end they have developed 3DL units through Backward Design. Laverty explained that they worked on assessment first because "if we don't assess what's important, then what's assessed *becomes* important." To do this they developed a 3D-LAP (Learning Assessment Protocol) to guide question authors and characterize assessments. As an example, Laverty pointed out that a question addressing the SEP of "analyzing and interpreting data" must address what is *claimed*, the *data* used to support the claim and how it is *analyzed and interpreted*. He said that the 3D-LAP evaluates questions according to which of the three dimensions are addressed. Analysis of texts and concept inventories by 3DL4US indicates that they are strong in addressing DCIs, less so in CCCs, and least in SEPs.

The SEPs are important in science teaching by the NGSS, because they call for science to be taught in the way it is practiced, as was pointed out by Paul Bergeron of MSU. To accompany the 3D-LAP, the 3DL4US project also developed the 3D-LOP (Learning Observation Protocol) to determine the degree to which instruction engages in 3DL. It is used to screen chunks of videotaped instruction for the DCIs, CCCs, and SEPs addressed and whether the instruction is instructor or student centered.

The SEPs were also important to Paul Nelson, also of MSU, who had also taught high school math for 12 years. He wondered how more college instructors could be persuaded to practice 3DL. If they felt that dealing with three dimensions of learning was too much at once, he argued that the SEPs are the key, because they define what students should be doing in active learning, while 3D-LAP and 3D-LOP data show that teaching and assessments address DCIs much more frequently.

Joseph Kozminski of Lewis University (IL), also focused on the SEPs in his talk on "Bridging Skill Development from NGSS to the AAPT Laboratory Recommendations." As the chair of the subcommittee which had developed those Laboratory Recommendations, Kozminski emphasized their importance along with the NGSS for the development of scientific literacy which is critical for *everyone* in the 21st century – to understand the technology which enabled the virtual meeting at which he was speaking, deal with climate change, develop alternative energy sources, and develop the oncoming field of quantum computing.

Kozminski indexed the six Laboratory Recommendations to the eight SEPs as follows: "Modeling," he pointed out, matches with SEP2 ("developing and using models), also with SEP5 ("using mathematics and computational thinking"). "Designing Experiments" matches with SEP1 ("asking questions and defining problems") and SEP3 ("planning and carrying out investigations"). "Constructing Knowledge" matches with SEP6 ("constructing explanations and designing solutions") and SEP7 ("engaging in argument from evidence"). "Analyzing and Visualizing Data" matches with SEP4 ("analyzing and interpreting data") and SEP 5 ("using mathematics and computational thinking"). "Communicating Physics" matches with SEP8 ("obtaining, evaluating, and communicating information") and SEP7 ("engaging in argument from evidence"). And "Developing Technical and Practical Skills matches with SEP3 ("planning and carrying out investigations").

Two speakers from the National Center for Improvement of Educational Assessment also spoke of their work. Carla Evans spoke on "Integrating the Three Dimensions of the NGSS into Rubric Design." Rubrics are not checklists or rating scales, she pointed out. Rather, a rubric is used to evaluate on a consistent basis the quality of a student's work – by listing criteria to be satisfied for each level of evaluation. When a rubric is presented to students, they know the criteria for success. She added that using rubrics often leads to their revision.

Evans spoke of four types of rubrics, in terms of two contrasting pairs. The holistic rubric, which gives only one score, was contrasted with the analytic rubric, which gives several scores and for this reason is more useful in giving more detailed feedback. Task-specific rubrics were contrasted with generic rubrics, and she noted that in the NGSS rubrics must strike a balance between being too general (generic) and being too (task-) specific. She suggested beginning with a generic rubric with SEPs and CCCs, then making it more specific by adding DCIs.

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NGSS in College Teaching

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Evans's colleague at the Center, Nathan Dadey, spoke on "Models of State Level 3D Assessment Reform." While he focused his remarks on the work the Center has done with NH, AL, MA, DE, and RI, he also listed several other NGSS Science Reform Approaches. For Curriculum and Instruction he listed the Stanford NGSS Curriculum & Assessment, Open Science Education (which has developed many successful open source high school curriculum units), NGSX (Next Generation Exemplar Program), STEM Teaching Tools, and NGSS Storylines. For Assessment he listed NGSA (Next Generation Science Assessment), SCILLSS (Strengthening Claims-based Interpretations and uses of Local and Large-scale Science assessment Scores) Project, SNAP (Stanford NGSS Assessment Project), and TAPS (Task Annotation Project in Science).

Kara Gray spoke of the work that she and her colleague Lane Seeley at Seattle Pacific University had done in "Using the NGSS Model of energy in university courses." This began from work with a group of high school teachers to consider the model of energy they need to teach their students and was then extended to elementary teachers with the advent of the NGSS (now available as an elementary energy curriculum at <https://focusonenergy.terc.edu>). Gray uses it in her Conceptual Physics for Future Elementary Teachers and Seeley uses it in her calculus-based physics course for physicists and engineers. Both courses employ guided inquiry and consensus building and seek to portray force and energy as two complementary models for understanding the world. They also emphasize that energy as a cross cutting concept plays a role in all the sciences, especially thermal energy.

The basics of their NGSS model of energy are that energy is 1) a conserved quantity, 2) located within objects or fields. It is 3) transferred between objects and 4) manifested in multiple forms, that are 5) indicated by observables. It is 6) transferred between forms, 7) transformed and transferred by mechanisms. It 8) trends toward a more even distribution and has 9) varying degrees of usefulness. Gray and Seeley seek to enable their students to construct this model for themselves, through what they call the Scenario Focused Energy Instruction Model, which begins with physical scenarios to give students a shared experience leading to energy representations to provide a shared language to formulate an energy model.

Cycles of scenarios are repeated as needed. They are specific, provide demonstrations or videos, and allow for further investigations. Sliding a box across a table both problematizes energy conservation and introduces energy forms. A second cycle, considering a gasoline-powered car on a level road at constant speed, could focus on the role of thermal energy in a conceptual course or on mechanisms of transformation or transfer for calculus-based learners. Gray showed a list of 20 scenarios in all.

They use three models of energy representation in dealing with their scenarios: energy theater (A. R. Duane, L. Wells, R. E. Scherr, *Phys. Teach.*, **52**(5), 291-294 (2014)); energy cubes, which represent units of energy that can be moved around among various parts of a system; and energy diagrams, which are a lasting representation containing language to use in formulating an energy model. Consensus building discussion is used to achieve the greatest generality possible.

2035 Report

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electricity production-cost model to generate the 90% Clean and No New Policy cases it compares. It also notes that further work is needed to assess "the effect of the 90% Clean case on loss of load probability, system inertia, and alternating-current transmission flows." (p. 13)

The Key Findings of the *2035 Report* are as follows.

1. "Strong policies are required to create a 90% Clean grid by 2035."

2. "The 90% Clean grid is dependable without coal plants or new natural gas plants."

This is established by running their model for "seven weather years," the worst hour of which was beset by a reduction of 18% below the rated wind capacity and 90% below the rated solar capacity (p. 17). The report assumes that there is flexibility in the "charging" of electric vehicles and heating of water and notes that "Increased electrification of the U.S. economy reduces the amount of battery storage required." (p. 19)

3. "Electricity costs from the 90% Clean grid are lower than today's costs."

"The base wholesale electricity cost under the 90% Clean case is 4.6 cents/kWh, about 10% lower than the 5.1 cents/kWh in 2020." (p. 21) This differs from earlier studies forecasting rising electricity prices because of declining costs of renewable energy and batteries – even though the 90% Clean case requires more spurline transmission costs than the No New Policy case. And by 2035 most of the fossil-fueled electricity-generating plants to be removed from service will have been fully depreciated, while in the No New Policy case new gas-fueled power plants will have to be constructed.

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2035 Report

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4. "Scaling-up renewables to achieve 90% clean energy [this should be "electrical energy"] by 2035 is feasible."

To achieve this, 1100 GW of renewable electric power generation must be added (this requires 70 GW/year), doubling our present 1000 GW generating capacity. The annual requirements are about twice the 15 GW wind added in 2017 and 19.4 GW solar expected in 2020. Present plans already call for the addition of 544 GW.

5. "The 90% Clean grid can significantly increase energy-sector employment."

The 90% Clean case will create 29 million job-years from 2020 through 2035, while the No New Policy case will create only 20 million job-years during this period.

6. "The 90% Clean grid avoids $1.2 trillion in health and environmental damages, including 85,000 premature deaths, through 2050."

These reduced environmental and health costs will result from an 88% reduction in carbon dioxide emissions, a 96% reduction in emission of nitrogen oxides, and a 99% reduction in sulfur dioxide. The premature deaths will be avoided by particulate matter reductions, a consequence of shutting down coal plants.

Supporting details of what must be done to achieve the goals of the *2035 Report* are spelled out in a 29-page paper, "Rewiring the U.S. for Economic Recovery," by Sonia Aggarwal and Mike O'Boyle of Energy Innovation, also released in June 2020. It cites the requirement of policies to establish a federal clean energy standard, incentives to achieve that standard, supports for those affected by the phaseout of coal, and facilitation for new transmission lines. Tables in this paper detail which agency should be responsible for each policy change.

The 37-page *2035 Report* can be downloaded from <https://www.2035report.com>. The URL for Aggarwal and O'Boyle's paper is <https://www.energyinnovation.org/wp-content/uploads/2020/06/90-Clean-By-2035-Policy-Memo.pdf>.

Online Physics Education

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Lastly, some institutions, including Guyamaca (CA), Barbara Jordan H. S. (TX), Southern Adventist, and Portland State, not knowing what equipment their students had at home, left it up to them to devise their own laboratory project from what they could find.

Energy Self-Reliance

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- The potential to generate electrical energy needs from conventional geothermal ranges from 0% (for most states) to 104% (Alaska).

- The potential to generate electrical energy needs from small hydro ranges from 0% (Texas, Rhode Island, Delaware, New Jersey) to 172% (Alaska).

When all this is added up, the potential to generate electrical energy needs renewably is over 100% for all states except Florida (59%), Alabama (92%), and West Virginia (96%) – but 18 states were in this category ten years ago. The report goes on to note that *all 50 states* could meet their electrical energy needs renewably if their *energy intensity* (number of kilowatt-hours required per dollar of GDP) were as low as that of New York.

Recognizing that many states are targeting 2050 to eliminate fossil fuels from all their energy uses, which means electrifying transportation, industry, and energy use in buildings 100% with renewable sources, this report notes that this could be achieved by the same 47 states that have the potential to generate all their electrical energy needs renewably (but only 41% in Florida, 67% in Alabama, and 73% in West Virginia). But if the requirement that other states reduce their energy intensity to that in New York, Florida (at 72%) would be the only state unable to provide all its energy renewably.

There are some caveats, however. This report assesses only the *potential* to generate electricity renewably. Achieving that potential requires building the necessary infrastructure, and the *2035 Report* in contrast clearly states how much must be added before its target year. In addition, *Energy Self-Reliant States 2020* acknowledges the requirement for energy storage in conjunction with generating electricity from renewable sources but doesn't factor it into its calculations, while the 20% of nuclear energy in the *2035 Report* can serve this function.

Energy Self-Reliant States 2020 can be accessed online at <https://www.ilsr.org/report-energy-self-reliant-states-2020/>.

(*Editor's Note*: *Energy Self-Reliant States 2020* is not the first interaction of the Clearinghouse with the Institute for Local Self-Reliance. I attended their conference on "Getting the Most from Our Materials: Making New Jersey the State of the Art" in New Brunswick, NJ, on 12 June 1991 and reported on it on the back page of our Fall 1991 issue.)

Computational Thinking addressed at AAPT

Although the mandate for including computation in undergraduate physics programs is the *AAPT Recommendations for Computational Physics in the Undergraduate Physics Curriculum* issued in September 2016, computational physics has been around as long as we've had computers. Indeed, the *AAPT Recommendations* cite a resource letter on the topic in the *American Journal of Physics* as early as 1996.

Several college professors discussed the role of computational physics in their undergraduate programs at this summer's online meeting of the American Association of Physics Teachers (AAPT). Tim Atherton of Tufts University described the real-world projects he had his students use computational physics to complete. He felt this combined computation with "making" and gave his students "agency." At the same session Steven Wolf of East Carolina University described how he expects his students to use a computer to analyze their laboratory data.

Theodore Bott of Michigan State University provided more detail in his presentation on "Navigating Computational Thinking for Introductory Physics Courses." In response to the question, "What is computational thinking?" he led off with a quotation from an article frequently cited by presenters at the meeting (Jeanette M. Wing, "Computational Thinking", *Comm. of the ACM,* **49** (3), 33-35 (March 2006): "Computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability." Bott's goal is to find ways that teachers can assess the "development of computational thinking processes in their students" and to this end he conducted a "literature review of existing CT [computational thinking] frameworks to establish a list of practices" to indicate CT in high school physics courses. From reviewing more than 10 frameworks – from elementary through university level – he has distilled a list of ten criteria to identify CT practices: 1) algorithm building, 2) modularizing, 3) abstracting, 4) choosing scale and units, 5) debugging, 6) decomposing, 7) iterative problem-solving, 8) utilizing generalization, 9) data practices, and 10) translating a model into code.

In establishing a list of criteria to indicate CT in high school physics courses, Bott extended the range of applicability of the *AAPT Recommendations* from 2016. He did this because "It's called for in the NGSS (Next Generation Science Standards)." Indeed it is, in the Science and Engineering Practice (SEP) of "using mathematics and computational thinking." There was an entire session devoted to computational thinking in physics at the high school level, and its leadoff speaker was Colleen Megowan-Romanowicz of the American Modeling Teachers Association, who described how she has taken the lead in establishing "Computational Modeling Physics First with Bootstrap." Acknowledging the aforementioned SEP of the NGSS, she observed that computers and algorithms have reshaped our world, but data science and programming have not yet penetrated K-12 education systematically.

To a computer scientist, Megowan-Romanowicz observed that computational thinking was formulation of a problem to be solved on a computer. But to a science educator it connotes a broad range of things "that bring the affordances of computers to the field of science education. . . ." However, she emphasized, "*it's not just coding*" – a phrase that was not to be heard for the last time.

How to bridge the gap between theory and practice, she asked. Her response was to establish a partnership between physics and computer science education. It's important to produce something teachers can use confidently and competently in their classroom, she added. Her goal has been an approach integrating computing with the physics that reaches all students at the level of Physics First. To achieve it she obtained funding for workshops in the summers of 2016 and 2017 in which teachers developed units for such a Physics First course that integrated Computational Modeling, using the Bootstrap language, *Pyret*. In the following two summers workshops were held to train teachers to teach the Computational Modeling Physics First course – a two-week workshop in 2018 and a three-week workshop in 2019 – followed by a distance learning workshop. After those four years, she found that students taught with Computer Modeling showed mathematical ways of thinking different from those in traditional Modeling Physics Instruction. And one teacher felt that "computing is a natural extension of Modeling Instruction."

Bob Hilborn, Associate Executive Officer of AAPT, reinforced and elaborated on what Megowan-Romanowicz had to say in his presentation, "Integrating Computational Thinking with Physics: What Does That Mean?" First he responded to the question "What is computational thinking?" with another quotation from Wing's article ("a broad framework of *problem solving* with computer algorithms") and another from David Weintrop ("a set of *practices*, things people do with computers"). And he agreed with Megowan-Romanowicz: "It's not just coding."

"What does *integrating* it [computational thinking] with physics mean?" he then asked. Delivering computational thinking and physics education together can be done in diverse ways, he responded. The intent is to *enhance* student learning and to enable solving more realistic and authentic problems, also to visualize the behavior of systems. His response to the question of what the

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Education about Quantum Computing

by John L. Roeder

For the past several years I have been reading articles hailing the promise of quantum computing, in which the "bits" of classical computers, which can exist in one of two definite states, 0 and 1 (the basis of the binary code which underlies all classical computers), are replaced by "qubits," which can exist in any combination of these two states. In particular, it was heralded for its value to factor numbers, which is significant for cryptography.

My reaction was to wonder how this could be carried out in practice, since the qubits would be made of subatomic systems, which behave according to the principles of quantum mechanics: how could the qubits be controlled and how could they be depended on not to change? When I learned that the New Jersey section of the American Association of Physics Teachers (NJAAPT) was offering a free online two-week workshop on Quantum Computing, I quickly signed up.

Professor Steve Schnetzer of Rutgers University patiently led us to learn the basics of simple quantum computer circuits and the mathematics used to describe them, and we were able to go to IBM's quantum computing website to design our circuits online and have IBM's quantum computers run them. One of Schnetzer's students, Eesh Gupta spoke to us about how he is using quantum computing to study lithium hydride. And one of Schnetzer's former students, Bharath Kannan, now at MIT, spoke to us about the qubits they have made by inserting a Josephson junction between two superconductors. I also learned that my concerns about the difficulty of controlling and maintaining the stability of qubits were not unfounded.

But the promise of quantum computing keeps its researchers in hot pursuit of this goal. I learned that at the 2019 summer AAPT meeting from the Physics Teaching Resource Agents (PTRAs), a group I originally became a part of in 1985 (as related on the last page of our Fall 1985 issue). I found that they had developed what they called a quantum initiative under their director, Karen Jo Matsler of the University of Texas at Arlington. The week after the Rutgers workshop I had also signed up to spend with the PTRAs at their 2020 Summer Institute, which was also being held online.

The first thing on every morning's agenda was a quantum workshop, based on materials from Perimeter Institute and the Institute for Quantum Computing in Waterloo, Ontario – Malus' Law, Heisenberg Uncertainty, Quantum Security, and Quantum Cryptography. The quantum initiative had grown into the Quantum for All program, funded by a grant from the National Science Foundation, as a result of Matsler's being invited to be part of a workshop of 25 representatives from industry and secondary and tertiary education at the behest of the National Science and Technology Council at the White House. That this workshop was held is an indication of how important the highest levels of government regard quantum computing as cutting edge technology, one that we must educate our students about.

Computational Thinking

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practical implications are is that computational thinking is more meaningful enhancing the understanding of physics than when physics stands alone. But he added that it does require professional development for physics teachers and appropriate curricular materials. He also voiced what he felt the *research questions* were: How to make this accessible to all students? What are the most effective pedagogical strategies and content development? What will be the effect on student attitudes?

To further the work that Megowan-Romanowicz had begun, Hilborn obtained NSF funding to hold conference of about 40 computer scientists and math and science educators on 2-5 May 2019 for "Advancing Interdisciplinary Integration of Computational Thinking in Science," which is also the title of the conference report available on the AAPT website (aapt.org – it can also be obtained directly by Googling the complete title). Among its recommendations is that computational thinking must not exacerbate existing inequities. Hilborn added that motivation to integrate it into physics courses also comes from the call from employers in the *Physics 21 Report: Preparing Physics Students for 21^{st} Century Careers* (also most easily accessed by Googling the complete title) for employees with computational skills and the wish from employees that they had been taught them. Hilborn closed his presentation with the hope that integrating computational thinking with physics for all students will be the New Normal for 21^{st} century education.

Also speaking at the same session was Richelle Teeling-Smith of Mount Union College – on "Computational Thinking in Introductory Physics: High School and Early College." She was one of the attendees at the conference Hilborn organized and defined CT *à la* Weintrop (who had been the plenary speaker at the conference) in terms of its role in data, modeling and simulation, and computational problem solving practices (the closest she got to "coding") and systems thinking. Teeling-Smith noted that teachers already do a lot of CT in their classrooms. Beyond this, adding computation gives a more realistic characterization of what physics is. It will also give students greater facility in dealing with models and simulations in whatever field they go into, she said. It will enable students to navigate between the "math world" and the "computer world." It also provides another representation in physics.

Workshop addresses nanoscience

by John L. Roeder

Because of the expected applications of nanotechnology to human lives, this subject has frequently graced the pages of this *Newsletter*. The earliest reference I could trace was our Winter 1992 issue, which reported on the 42-page section devoted to the subject in the 29 November 1991 issue of *Science*, which also reprinted Richard Feynman's February 1960 talk, "There's Plenty of Room at the Bottom," credited with inspiring this field of research. But there has been no coverage of the subject since our Fall 2011 issue, so when I learned of an online workshop on the topic on 3-7 August 2020, I quickly signed up. It was led by Mariel Kolker, teacher of physics, nanotechnology, and engineering at Morristown (NJ) High School, with support and assistance from Pinar Akcora, Professor of Chemical Engineering at Stevens Institute of Technology, and Rahmi Ozisik, Professor of Materials Engineering at Rensselaer Polytechnic Institute.

Kolker was careful to show how everything in the workshop related to the Next Generation Science Standards (NGSS). Nanoscience, she stated, embodied the Cross Cutting Concept (CCC) of Scale, Proportion, and Quantity and the Disciplinary Core Idea (DCI) HS-ETS1, Engineering Design. It also applies the Science and Engineering Practices (SEPs) of Asking Questions and Defining Problems and Constructing Explanations and Designing Solutions. Kolker also sought to structure the workshop in terms of presenting *phenomena* as an *anchor* to *engage* students and also serve as a common thread throughout a unit.

The nanoscale, between 1 and 100 nanometers, Kolker pointed out, is governed by quantum mechanics, with electromagnetic forces dominating over gravity. In addition to quantum mechanics and electromagnetic intermolecular forces, she said, surface effects and Brownian motion complete the quartet of phenomena responsible for nanoeffects. She showed a video, "A Boy and His Atom," made from IBM's scanning electron microscope pictures of arrays of atoms, and a set of graphs showing that China and the European Union have overtaken the U.S. in nanopublications, with China overtaking the U.S. in patents as well. Another video explained that the 100 nm upper limit of the nanoscale is the size of one of the eyelashes on the statue of Abraham Lincoln in the Lincoln Memorial on the back of an American penny.

Solar Cells

After the general introduction to nanoscience on Monday, the succeeding days were devoted to specific nanoscience topics. The topic on Tuesday was Solar Cells, for which the pertinent DCIs were PS3.D, Energy in Chemical Reactions, and PS4.B, Electromagnetic Radiation. Kolker had us watch Richard Komp's YouTube video, "How do Solar Panels Work?" before class, so that we would know that the conventional silicon solar cells were actually two layers – one of n-doped silicon, which has extra electrons, the other of p-doped silicon, which has a deficiency of electrons (known as "holes"). Because some of the extra electrons in the n-layer migrate into the p-layer at what is called the p-n junction, they set up a field opposing the flow of more of them, so that when sunlight strikes an electron in the n-layer and excites it, the field at the p-n junction forces the excited electron to pass through the circuit connected to the solar cell where it gives off its energy just like an electron energized by a battery. The electron is the only moving part in a solar cell.

Then Kolker pointed out to us that silicon solar cells are rigid and relatively expensive, requiring a vacuum for their manufacture and four years of energy production to offset their production costs. In contrast, she went on to tell us that the Dye-Sensitized Solar Cell (DSSC) is more easily manufactured, and without a vacuum, is flexible (it can be rolled up), and requires only three months of energy production to offset its production costs. The specific DSSC Kolker considered had indium tin oxide on the glass anode, next to it a layer of nanoporous titanium dioxide which absorbed the anthrocyanin dye next to it, then an electrolyte between it and graphite on the glass cathode. Since the anthrocyanin dye is red, it absorbs green light. When sunlight ejects electrons from the dye, the dye is oxidized and subsequently reduced by a reaction in the electrolyte, which is reversed when the originally ejected electron completes its path through the circuit and returns to the cell at its cathode.

Another video took us to a further level in solar cells – *transparent* solar cells. It pointed out that that the purpose of solar cells is to absorb sunlight and convert it as efficiently as possible to electrical energy of electrons in a circuit. But what if the only absorbed part of the spectrum of sunlight was the invisible part, namely infrared and ultraviolet, which the video claimed comprised 22% of the total radiation in sunlight. Such a transparent solar cell could be used as a window or a cover for a window. They could be mounted on skyscrapers to generate an abundance of solar electricity – right where it is needed, thus not needing to build expensive long transmission lines.

Another application of nanostructures to solar cells, which has been referenced in previous issues of this *Newsletter*, is quantum dots, made of various areas of semiconductors, with the energy band gap increasing inversely with the size of the "dot." This allows the color

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of light absorbed by the quantum dot to excite an electron from its valence to its conduction band to be "tuned" by the size of the dot. If not connected to circuits, quantum dots will simply fluoresce by emitting the light they have absorbed, with the color thus varying with the size of the dot. Kolker noted that quantum dots must be kept refrigerated – but she exclaimed that they glow! In this mode of operation, quantum dots can be used to measure the frequency of light in stellar spectra and in medical imaging. They can also emit light of whatever color is desired in television monitors.

Bionanoengineering

Wednesday's topic was Bionanoengineering, and the relevant DCIs from the NGSS were PS1.A, Structure and Properties of Matter, and PS2.B, Types of Interactions. These are both physical science DCIs and no life science DCIs are relevant here, Kolker pointed out, because bionanoengineers use DNA for its structural rather than its biological properties. They seek to design new structures with DNA building blocks, but they do use biological nanotools to do this: ligases, enzymes, and polymerases.

Kolker enumerated the advantages of DNA as a structural material to bionanoengineers: it has a high degree of structural programmability, permeability, and biocompatibility. The advantage of biocompatibility is important when it comes to designing nanorobots for medical treatment --- they are envisioned as medical diagnostic tools or as vehicles to deliver chemotherapeutic, biological, or immunotherapeutic agents. Kolker pointed out that they can be controlled chemically (by pH, enzymes) or physically (by light, magnetism, temperature) but added that they also need to have a source of mobility. In one of the videos we were assigned, Nils Walter of the University of Michigan described a DNA "walker" that flips from one nucleotide to another up to 43 times a minute, with a velocity up to 300 nm per minute. As already noted, quantum dots are expected to play an important role in medical imaging.

Another role for DNA in bionanoengineering is in data storage and computing. DNA data storage would convert the 0s and 1s of classical computing into As, Cs, Ts, and Gs, for the four nucleotide bases of DNA. The motivation to do this is the difficulty of keeping up with our present data storage facilities to store the increasing amounts of data being generated. In contrast, DNA storage density would be dense (Kolker cited a density of 215 Pb/gram); it would also be stable and require low power. In one of the YouTube videos we saw, a company named CATALOG claimed to have stored a Tb of data in DNA and is aiming to store the Wikipedia in the same way – and they claim that doing it in liquid makes it easier to access.

The advantages of using bionanoengineering are the same for computing as for data storage. Another YouTube video portrayed biocomputers manipulating the muscle protein myosin (which Kolker said has the ability to convert chemical energy from ATP to mechanical energy, as happens in muscle contraction). These biocomputers are seen as rivals to quantum computers in doing supercomputing tasks, and Kolker said that they would use less than a hundredth the power of equivalent electronic computers and, moreover, operate at ambient temperature (electronic computers require cooling and some quantum computers require extreme cooling to superconducting temperatures).

Gecko Adhesion

One of the DCIs pertinent to bionanoengineering (PS2.B, Types of Interactions) was also cited as pertinent to the first of two topics covered on Thursday, Gecko Adhesion. The phenomenon here was geckos walking upside down on a ceiling, Kolker said. The related guiding question was how to investigate the relationship among contact area, force, and sticking of the gecko.

Observing that ants can suspend almost 100 times their weight while being suspended upside down, Kolker calculated that each of their feet could suspend 6.7×10^{-6} newtons of force. To be suspended upside down, a gecko weighing 2.2 N would therefore need 330,000 ant feet (and a human 120 million of them). Of the quartet of phenomena responsible for nanoeffects Kolker had cited on Monday, electromagnetic intermolecular forces and surface effects were the two important factors here. Through YouTube videos we learned that geckos have flexible toes that can spread out onto a ceiling to provide maximal contact area and that those feet are covered with hairs that have ends looking like spatulas. Those spatulas in turn contain polar molecules that form van der Waals forces with polarized molecules in the ceiling. To release a foot to take a step, the gecko can curl up its toes to reduce the surface contact area.

The gecko's ability to adhere to a surface and, in doing so, defy gravity, has found application in our lives to everything from tape to humans climbing up vertical surfaces, using mitts covering the hand which maximize surface contact and van der Waals forces that are connected to L-shaped structures for the feet to stand on (we saw a video of that, too).

Superhydrophobicity

The other topic covered on Thursday was quite the opposite: Superhydrophobicity, for which the relevant element of the NGSS was Performance Expectation HS-PS2-6, Molecular-Level Structure of Designed Materials. Instead of finding ways for molecules to adhere to each

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other, superhydrophobicity seeks to keep water from adhering to other materials. Whereas polar molecules adhere because of the van der Waals force between them, the secret of keeping polar water molecules from adhering to something else is to shield it with a non-polar substance. We learned that lotus leaves do this naturally by their roughness and a wax coating (Rahmi Ozisik interjected that the rougher the surface, the more hydrophobic it is), and we saw how this is done with "magic sand" by making sand (silicon dioxide) non-polar by bonding carbon atoms, to which three methyl groups are bonded, to exposed oxygen atoms.

But even more dramatic was a product called "Ultra Ever Dry" – when a bucket of muddy water was thrown at a man who had been protected with it, the muddy water rolled right off him. Ozisik pointed out that the degree water molecules permeated another surface could be measured by representing the water molecule by a portion of a sphere above the surface and measuring the "contact angle" between the supporting surface and the surface tangent to the sphere at the supporting surface. A water molecule that made no penetration into the surface would be represented by a complete sphere atop the surface, and the surface tangent to the sphere at the supporting surface in this case would form a 180-degree angle with the supporting surface.

CRISPR

We had our choice of Molecular Modeling or CRISPR on Friday, and I chose CRISPR, because I wanted to learn something about it. The relevant elements of the NGSS were DCI ETS1.B, Developing Possible Solutions, and Performance Expectation HS-LS3-1, Chromosomal Inheritance. CRISPR is an acronym for Clustered Regularly Interspersed Short Palindromic Repeats, which, along with the protein Cas9, recognized as the basis for a gene-editing system in 2012 by Jennifer Doudna and Emanuelle Charpentier, who were awarded the Nobel Prize in Chemistry two months after the workshop. From videos, one of them a TED talk by Doudna herself, we learned that they had taken their cue from what had already been realized for a few decades in the behavior of many bacteria.

Scientists had recognized that many bacterial genomes contained identical CRISPR separated by non-identical pieces of DNA, which turned out to match the DNA of viruses that had previously invaded the bacterium, and a set of genes that made Cas proteins, some of which unwind DNA (helicases) and some which cut it (nucleases). When invaded by a new virus, the bacterium would make up RNA copies of the DNA it had stored from all the previous viral invaders and attach this "guide RNA" to a Cas9 protein to be sent to check against the DNA of the newly-invading virus. If there was a match, the Cas9 would cut the DNA of the newly-invading virus. If not, the Cas proteins would cut out the new section of DNA from the invading virus and add it to the samples already included in the bacterial genome. In either case, the CRISPR Cas9 system served as an immune system to protect the bacterium from viral attack.

If bacteria could cut DNA from an invading virus with Cas9 and guide RNA formed from a sample of that DNA already stored in its genome, why couldn't DNA in another organism be cut wherever desired by combining an appropriately assembled piece of guide RNA and Cas9? That's what Doudna and Charpentier realized.

Although CRISPR Cas9 allows for editing DNA with unprecedented precision, its use to treat monogenetic diseases is not without safety concerns, Kolker pointed out. What if there are several sequences in the genome matching the one to be edited, she asked? How could they be distinguished so that the Cas9 cuts in the right place? And what if an edited gene plays an additional role in the body beyond the one for which the editing is done?

Additionally, Kolker pointed up four ethical concerns concerning CRISPR Cas9:

1. *Ecological Equilibrium* – modifying or inserting a gene (called a gene drive) that becomes dominant and leads to widespread unintended consequences.
2. *Regulation* – Who would be in charge of regulating the use of CRISPR Cas9? Would they be scientifically knowledgeable?
3. *The Human Germline* – the possibility of genetically modifying an embryo for desired characteristics.
4. *Fairness and Equality* – Is CRISPR available only to those who can afford it?

In addition of sharing a wealth of knowledge at the workshop, Kolker also called our attention to several useful websites which can enhance our teaching:

Phenomena and NGSS Resources:

https://www.nextgenstorylines.org: This website of "the Next Generation Science Storylines project is dedicated to providing tools that support teachers in developing, adapting, and teaching with strongly aligned NGSS materials in classrooms around the country." The highlighted sections are "What are Storylines?" and "Tools for Creating and Working with Storylines."

https://www.openscied.org/access-the-materials: NGSS-aligned science units for grades 6-8.

http://georgiascienceteacher.org/phenomena: location of GSE (Georgia Science Education) Phenomena Bank.

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The STEP UP Physics Program

by Frank Lock

In the Spring of 2019, I received an email requesting qualified people who resided in the southeast to apply to be a STEP UP physics Ambassador. I was aware of the program from previous information I had received, but I had not applied due to other obligations. When I learned of the need for Ambassadors located in the southeast, I applied to support the program. Encouraging women to pursue careers in physics and related to physics had been one of my primary goals as a high school teacher.

STEP UP is a project sponsored by the National Science Foundation and is a collaboration of the American Physical Society (APS), the American Association of Physics Teachers (AAPT) and two research institutions - Florida International University (FIU) and Texas A&M University-Commerce (TAMUC). It is designed to mobilize thousands of high school physics teachers to reduce barriers and inspire young women to pursue physics degrees in college through materials for high school classrooms, freely available at the STEP UP program site <https://engage.aps.org/stepup/curriculum>.

The STEP UP Project Goals are to

- Mobilize thousands of high school physics teachers to help engage young women in physics
- Change deep-seated cultural views about who does physics
- Inspire young women to pursue physics in college

These goals are achievable using the materials created by STEP UP researchers. These researchers have also shown that most women pursuing physics majors report that they became interested in physics careers in high school (Hazari, Brewe, Goertzen, and Hodapp, 2017). A high school physics teacher's recognition of a young woman as being a "physics person" is a significant predictor for choosing a physics career.

The leadership of the STEP UP project is dispersed over the four partner institutions. The project management team is comprised of professional societies, researchers, project managers and support staff. FIU and TAMUC lead the research, while APS is responsible for recruiting teachers to the movement, while AAPT oversees the Ambassador Program.

There is an Ambassador Program Coordinator and seven Ambassador Leads supporting our Ambassador Program, a key recruitment element of the project. The second Ambassador cohort began in March 2020 and is comprised of 80 teacher leaders.

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Diversity and Implicit Bias in the Geosciences

by Michael J. Passow
Earth Sciences Correspondent

In recent years, it has become clearer that consciously or unconsciously, much of what happens or does not happen in the geosciences is affected by implicit biases and a lack of diversity.

All major professional organizations are taking steps to "move from statements of solidarity and support, so the focus is now on the essential tangible actions." The American Geophysical Union (AGU) has identified eight action areas for implementation:

1. Expand Funding for AGU's D&I efforts
2. Diversify AGU's Governance and Committees
3. Enable, Recognize, and Reward Diversity in our Honors
4. Create Truly Diverse Meetings
5. Review diversity, equity and inclusion across AGU's Publications
6. Support the Success of Emerging Underrepresented Scientists
7. Advocate for Policies that Eliminate Racial Injustice
8. Partner with Leaders across STEM to Remove Systemic Racism and Foster Culture Change

(Source: https://news.agu.org/files/2020/08/Eight-Area-Steps-AGU-is-Taking-to-Address-Racism-in-our-Community-FINAL.pdf)

Attempts to quantify the situation reveal the low numbers of geoscientists from underrepresented groups, as demonstrated by the graph at the bottom of page 14.

Major geoscience institutions, such as the Lamont-Doherty Earth Observatory (LDEO) of Columbia University, are making concerted efforts to examine and rectify problems resulting from implicit bias. The Office of Academic Affairs and Diversity at LDEO is committed to fostering a diverse, vibrant, and inclusive work environment at Lamont. Housed in the Lamont Directorate, this office was created in 2008 as a response to the recommendations of the National Science Foundation (NSF) ADVANCE program. Diversity, equity, and inclusion (DEI) are integral to our achievement of academic and scientific excellence, and this office has developed and implemented a wide range of initiatives impacting different groups across campus.

Actions already underway include monthly gender and diversity coffee hours, LGBTQ+ Inclusivity and Lamont Pride Socials, Navajo Nation Outreach, and Wom-

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The STEP UP Physics Program

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The STEP UP Ambassadors are a group of STEP UP teachers and members who are committed to empowering fellow teachers to inspire young women to pursue physics. This is done through training and supported implementation of the STEP UP curriculum in classrooms around the country.

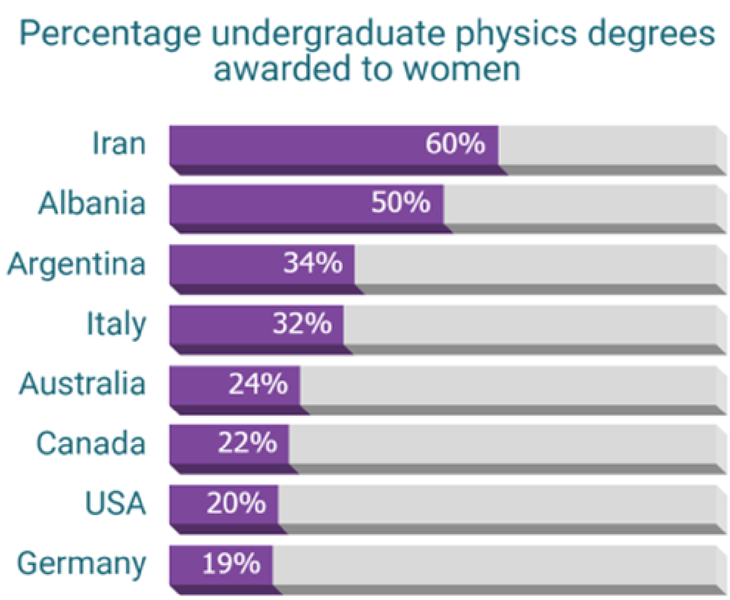
For the 2020-2021 cohort of Ambassadors there are 85 instructors including the program coordinator and leads. In conjunction with the AAPT Summer Meeting, STEP UP holds a Summit to prepare the instructors to present the curriculum to be used by the teachers recruited to the STEP UP program, and to use the curriculum in their classes. The materials consist of three sets of lessons: *Careers in Physics, Women in Physics*, and *Everyday Actions*. The professional development in which the teachers participate prepares them to use these lessons with their students. So far, the Ambassador program and other recruitment efforts have brought an additional 950 high school teachers to the community of STEP UP supporters.

The international context of women in physics is an important aspect to the STEP UP project, as we are hoping students will grapple with the societal factors that underlie stereotypically gendered professions such as physics. The graph at the bottom of this page is incorporated into our *Women in Physics* lesson and shows where the U.S. ranks in the number of women earning physics bachelors' degrees compared with seven other countries – seventh of eight.

Data indicate that in high school classrooms in the U.S., nearly 50% of high school students enrolled in physics classes are women. In introductory college physics classes enrollment by women drops to 20%. That data indicate that women in high school may not receive enough information about the variety of careers available to those having an undergraduate degree in physics, as well as the job satisfaction reported by women in careers in physics and related to physics.

I was accepted to participate in the STEP UP Ambassador training sessions in July 2019, held in conjunction with the AAPT summer meeting in Provo, Utah. As a retired teacher, my emphasis was on informing physics teachers in my area about the STEP UP program and encouraging them to utilize the curriculum materials available. A second cohort of Ambassadors was formed and trained virtually in the summer of 2020, and I was fortunate to be invited to participate.

The STEP UP program is involved in important work supporting the professional physics community, and making college-age women aware of the career possibilities that exist to people who earn an undergraduate degree in physics. For information about becoming involved in the STEP UP program, visit the website <https://engage.aps.org/stepup/> or contact Frank Lock at <lockphys@gmail.com>.



Diversity and Implicit Bias

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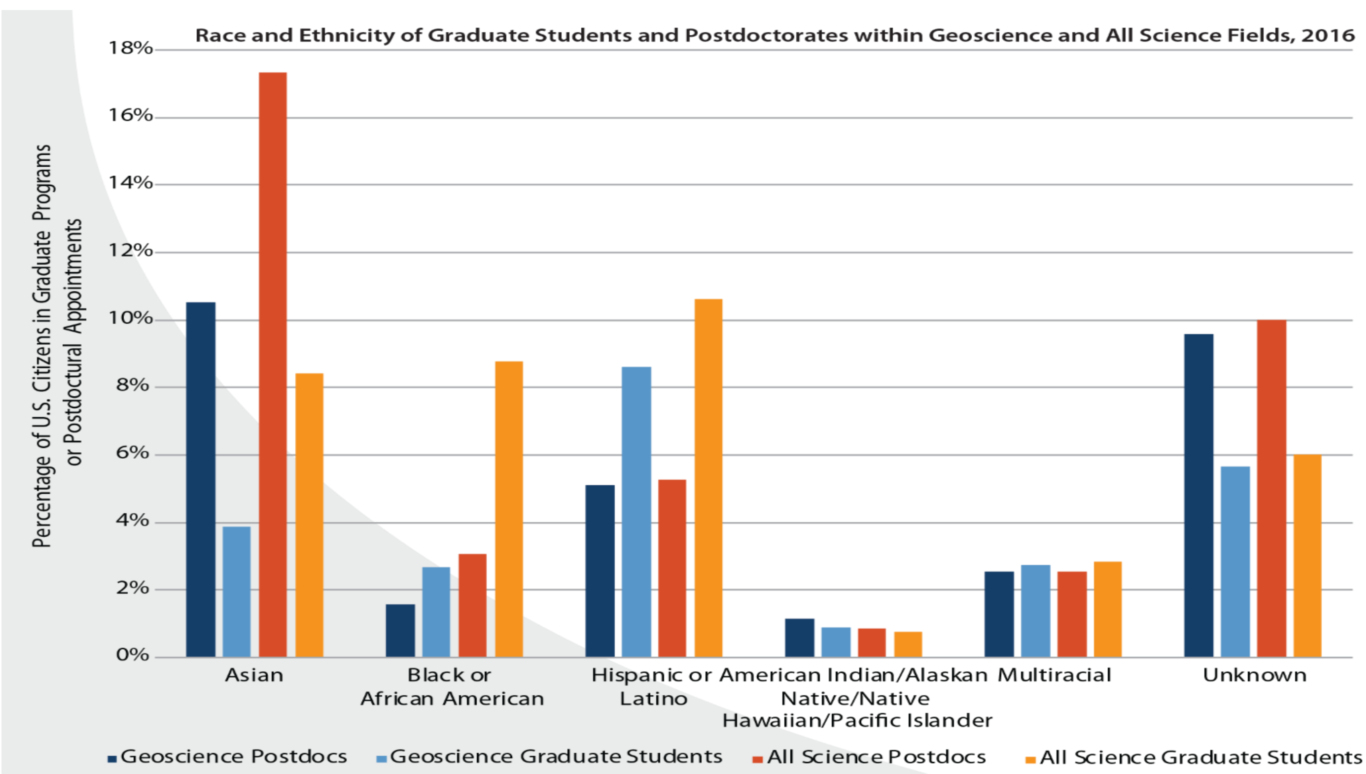
en's Networking Events. (https://diversity.ldeo.columbia.edu/sites/default/files/content/Dutt%20Lamont%20Diversity%20Report%202019.pdf) Following a racial email attack in May 2019, there has been increased discussion of racial bias awareness. The office is led by Dr. Kuheli Dutt, who presented the first Earth2Class workshop presentation in the current academic year (https://earth2class.org/site/?p=16794).

Many other universities are undertaking similar programs. Selected examples include the University of Virginia (https://vpdiversity.virginia.edu/), Harvard University (https://college.harvard.edu/life-at-harvard/diversity-inclusion#:~:text=Harvard%27s%20commitment%20to%20diversity%20in%20all%20forms%20is,creates%20the%20conditions%20for%20dramatic%20and%20meaningful%20growth.), Princeton University: (https://odi.princeton.edu/), and Notre Dame University (https://diversity.nd.edu/).

Regardless of however well-meaning such attempts are, the fact remains that there is a long history of bias and exclusion to overcome. Of course, another key component in seeking solutions involves the diversity "in the pipeline." The number of students from underrepresented groups in private and public high schools heading into STEM majors remains low. One key example is the Bronx High School of Science, one of the top schools in New York. Their diversity score is 0.50, indicating relatively little diversity. The largest group of students is Asian, followed by White and Hispanic (https://www.publicschoolreview.com/bronx-high-school-of-science-profile#:~:text=The%20school's%20student%3Ateacher%20ratio,flat%20over%20five%20school%20years.). At the Horace Mann School, 42% of the students identified as "students of color" (https://www.horacemann.org/our-school/office-for-identity-culture-and-institutional-equity). Most other schools are developing enhanced "anti-racist" plans, such as The Calhoun School (https://www.calhoun.org/about/diversity). One fact remains that until there are a sufficient number of students from underrepresented groups entering STEM programs in colleges, we may see little change in the statistics. On the other hand, greater awareness of implicit bias may reduce some of the stress that students will face as they go through schooling and careers.



(Source: https://www.americangeosciences.org/geoscience-currents/race-and-ethnicity-us-citizen-geoscience-graduate-students-and-postdoctoral)

ALL ABOUT LINES (and shapes)

by Bernice Hauser
Primary Education Correspondent

Can you recite a line from your favorite poem?
Can you sing a line from your favorite Broadway tune?
Can you recollect an infamous line from the past?
Can you recall a newsworthy photograph of individuals standing on line?
Are you now on line waiting to purchase some groceries or to board a bus?

In a *Wall Street Journal* article, dated 12-13 September 2020, Eugenia Chen recently posited some responses to the question: what is a line?

"For instance, Euclid did not define a line, he instead articulated the role they play in geometry. Euclidean geometry is essentially the one in which straight lines have the equation $y = mx + b$. Other types of geometry include spherical geometry, in which lines are drawn on a sphere like the surface of the earth and hyperbolic geometry, which is what happens on the surface of a horse's saddle."

And if one pursued the definition of "line" in an ordinary dictionary they would discover a multitude of explanations and definitions for this word/mathematical concept.

Due to the current pandemic crisis, we are on line constantly – either virtually or physically – and in response to two random encounters that I recently had, I thought an article on lines might prove timely to our readers.

I played this out with several adults recently. Here is the list of lines that they suggested: *railroad lines, lines at gas stations, telegraph lines, frown lines, lines of poetry, social distance lines, lines of inquiry, headlines, bylines, lines of communication, property lines, ancestral lines, lines of credit, protest lines, parallel lines, fishing lines, gas lines, clothes lines, subway lines, laugh lines, hotlines, outlines, receiving lines, being online, party lines, land lines*, *mobile lines, latitude lines, longitude lines, between the lines.*

My Two Encounters

Upon visiting the reopened Metropolitan Museum of Art, I overheard a young child looking at a photograph of Georgia O'Keeffe and asking his attendant why this individual had so many *lines* on her face? The child's attendant wisely and artfully explained, that those *lines* are a sign of aging – that some individuals develop lines on their faces, sometimes called wrinkles or lines of wisdom, others may need to wear hearing aids like his grandfather Ben, or perhaps they may walk with a cane, and many more may need to wear eyeglasses to see better. They then moved on to the next portrait – her explanation appeared to satisfy the young child's inquiry.

Across America this pandemic has forced many businesses to obey restrictions and rules alluding to how many individuals may enter a place of business. Recently waiting online at Trader Joe's, I overheard a young person ask her mother, who was third in *line*, how much longer would they have to wait on*line* before they could shop at this store?

I was still conflicted about writing about lines when my face to face encounter/conversation with this six-year-old removed any remnant of doubt. (Her parent gave me permission to converse with her.)

"May I ask you a question?"

"Yes."

"If I say the word *line* or *lines* to you, what does that make you think about?"

"I think of the letter N that we practiced printing today on a special *lined* paper; my teacher also made us stand tall and then place our right hand in a slant down to our left foot. "Two straight *lines* and one slanted *line,*" she said. We also had a cardboard N to trace and we then made a list of all the words we could think of that started with the N sound. It was so funny: everyone shouted out 'no' or neighed like a horse…" (The letters A and N are often used in early childhood classrooms to begin the discussion of lines.)

"Anything else about the word *line* or *lines*?"

"Well, I don't like standing on the cafeteria *line* because some children are so slow in choosing their dishes that sometimes I do not have enough time to finish my lunch."

Realizing the limited exposure to the subject of lines these children exhibited, I wondered how we adults could expand and enrich the opportunities to explore and investigate lines in their environments.

A Colleague's Experiences

Here's how one educator, a colleague of mine with whom I had shared my observations of children and lines, seized the opportunity to initiate an interest in lines. (This is in a classroom of four- and five-year-old students.)

These teachers coming back to school this fall discovered that the sidewalk next door was being repaved. They

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LINES (and shapes)

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received permission to bring their young charges out of the school building to see how cement was flowing from the cement/asphalt-making truck, and how the workers were using special tools to apply this material to a new pavement. The students were also directed to note the extreme care to their making space lines between each new pavement square.

A student asked the teachers why they were doing that. They suggested that the student direct the inquiry to the workers. Their response was that the material used to create the pavement square expands or swells or gets fatter when it gets hotter. The cement needs some extra room to expand into when the temperature increases or the new pavement will start cracking up and be dangerous to pedestrians. They observed the strips placed over each line and the barriers placed around the new sidewalk to prevent anyone from disturbing the wet material hardening and drying.

The teachers in charge did not know whether to follow up on materials expanding when they get hotter or not – they decided not to pursue this line of inquiry just now. Seizing the opportunity to delve more into this topic of lines, they compiled some activities utilizing the classroom and its materials toward this purpose.

They formed pods of four children each — hence three pods — one pod was to explore the walls of the classroom for anything seen relating to lines, another pod was to explore the materials located on the floor of their classroom, and another pod was to look at the materials on the shelves. The teachers set up three headings on a white board – each pod could record their findings – they could draw pictures or ask the co-teacher to list their findings under each specific heading.

Among the things they found were window frames, tiles on the floor, the lines on blocks, the lines on notebook paper, the lines of the different letters of the alphabet, lines on their sneakers, lines on their socks, lines on their straws, and lines on the panes of glass in each window.

Going from the familiar, the students then printed out their names on lined paper. (They recently have learned to print their names on every item they create.) At the same time one teacher printed NINA on the white board in addition to creating a three-dimensional NINA with the wooden letters stored in a bin in the classroom. She had the children stand and, working with a partner, physically duplicate each letter. She then asked for a volunteer to describe how he would make the letter N on his ruled lined paper. She had the class, following his instruction, create the letter N using their arms in the space around them. She then had them practice writing the letter N on their lined paper. The co-teacher, who is the NINA in discussion, observed that some students made two straight lines and then added the slanted line and shared this observation with the other teacher.

Next came time out to validate each pupil's rendering of this letter while also advocating for a faster way of duplicating this letter. Each child had a turn to craft this letter on the white board. The children noticed the different ways used. They then had a discussion and voted for the easiest and fastest way to write an N. NINA was an excellent choice to show straight and slanted lines and lines that converged to a point. They then studied each letter of the alphabet to describe how it is fashioned, with straight lines, curved lines, and circular lines.

Moving on, the educators then crafted lessons on shapes and used material in the actual classroom as concrete objects to explore. Using the plethora of wooden building blocks found in early childhood classrooms, the children examined and classified them by shapes, talked about corners (angles) and lines on these shapes. They learned to identify basic shapes like square, rectangle, and circle. One activity that they engaged in was to cut a circle into four parts using just two lines. A discussion was initiated about segments like dividing an apple pie into four equal shares or four unequal shares. New definitions were posted: equal, unequal, one half, divide, share, one quarter. One enriched activity was giving children reusable round picnic plates plus three strings (substitutes for lines) and ask them to divide the circle into seven parts. None of the students was able to actuate the correct result, a teachable moment for these educators.

The students cut out photos of faces from newspaper clippings and talked about long faces, round faces, square faces. They took a walk outdoors to classify the shape of the buildings on their school block as well as classifying the shape of their own school building. They then created their school building by using discarded cardboard cartons, construction paper, paint, to make a small model of their school building, labeling every feature of the building.

This led to private discussions by the teachers of possible future activities and projects that could be follow-ups to the initial study of lines such as "how do we communicate," "where does our drinking water come from," and "different houses."

Older students can classify lines into categories. The analytical, advanced scientific inquiry process kicks in when we ask these same students to read up on the proposition regarding a new *gas line* being placed on lands belonging to Native Americans. In their algebra classes and geometry classes and physics classes, the study of lines will elicit a different a response. For example, the

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LINES (and shapes)

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strength of the material used in specific lines will determine their function and usage in different objects.

In NYC, they are always digging up the streets to repair a rupture in a gas line, or put in a new cable line for TV subscribers – I wonder how many of us actually consider what is buried under our sidewalks and streets. That could be a project for teachers in urban areas.

Educators may ask children in rural areas to look at the lines on their highways and roads, at property line demarcations, or at the electric lines overhead in rural areas that are often decimated in storms and hurricanes. Headlines in the daily newspapers often show these high-powered lines lying on the ground, or sparking a fire that can destroy acres and acres of land.

Early childhood educators need not look afar for materials and activities to expand their charges' knowledge of how the world works. Just look carefully at your environment and a plethora of ideas will reward your steadfastness and studious attention.

References:

Tana Hoban, *Shapes, Shapes, Shapes* (Greenwillow, 1996)

Anne Miranda and Eric Comstock, *Tangled: a story about shapes* (Simon & Schuster/Paula Wiseman, 2019)

Chakra Sreekanth, Sreekanth Kumar, and Emily Zieroth, *All Shapes Matter* (Chakra, 2018)

Roseanne Thong and John Parra, *Round is a Tortilla: a book of shapes* (Chronicle, 2013)

Ellen Stoll Walsh, *Mouse Shapes* (HMH, 2007)

(*Editor's Note*: To this list of references I would like to add one that I gave to my not-yet wife in 1966: Norman Juster, *The Dot and The Line: a romance in lower mathematics* (Random House, 1963).)

Foster discusses paths to sustainable energy

Scott Foster is the Director of the Sustainable Energy Division at the United Nations Economic Commission for Europe (UNECE). On 16 July 2020 he made a presentation to the OECD Nuclear Energy Agency describing UNECE's *Pathways to Sustainable Energy* project, which seeks to enlist the support of all countries to bring all possible options to provide the energy we need in a way that keeps the temperature of the atmosphere from increasing two degrees above its present value, rather than the four to six degree range he foresees from business as usual. "We're going to have a proper placement of nuclear, nigh-efficiency, low emissions technology for fossil, hydrogen, renewables, energy efficiency, and the rest of it," he said, adding that "there *does* need to be a real price on carbon."

Foster saw carbon neutrality as "a stepping-stone to the cost-effective attainment of sustainable energy," and he saw energy as the *golden thread* that connects the U.N. Sustainable Development Goals (described in our Winter/ Spring 2018 issue). Except for noting the need for a *just transition* for today's large industrial complexes that are highly dependent on carbon, Foster spelled out few specifics to reach energy sustainability, but he did recommend seeing energy as a *service* to provide services like heating and mobility rather than a commodity like kilowatt-hours of electricity or tonnes of coal.

nanoscience

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https://thewonderofscience.com/phenomenal: aggregation of phenomena indexed by grade level and NGSS performance expectations.

https://www.nnci.net/search/curriculum: large, searchable collection of nanoscience lessons and activities for K-12 classrooms.

https://education.mrsec.wisc.edu/k-12-educators/: several lesson plans, also kits that can be purchased for classroom labs.

http://www.trynano.org/resources/nanotechnology-lesson-plans: lessons, nanotechnology links

https://www.nano.gov/: resource with lessons, tutorial pages, videos, links, and nanotechnology news.

https://nanosense.sri.com/activities.html: Four units (Size Matters: Introduction to Nanoscience; Clear Sunscreen: How Light Interacts with Matter; Clean Energy: Converting Light into Electricity; and Fine Filters: Filtering Solutions for Clean Water), indexed to conventional high school science topics.

http://teachers.egfi-k12.org: website established by the American Society for Engineering Education where teachers can access lesson plans, class activities, and K-12 outreach programs for grades K-5, 6-8, and 9-12 for a host of STEM topics. Other resources are also available.

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Mark Wilson, "An Alaskan volcano, climate change, and the history of ancient Rome," *Phys. Today*, **75** (9), 17-20 (Sep 20).

The assassination of Julius Caesar in 44 BCE ended the Roman Republic and led to a tempestuous period that ended with the emergence of his grandnephew Octavian as the first emperor of the Roman Empire. Analysis of Arctic ice cores, tree rings in Sweden and Austria, and Chinese stalagmites show that Nature played a role in this with an unseasonably cold 43-42 BCE. The culprit was eruption of Alaska's Okmok volcano, whose basalt matched that found in the ice cores, along with insoluble tephra and sulfur which mark volcanic eruption. The cooling results from oxidation of emitted sulfur dioxide to sulfate, which forms particles that scatter incoming sunlight.

2. Pnina Geraldine Abir-Am, "The Women Who Discovered RNA Splicing," *Am. Sci.*, **108**(5), 298-305 (Sep-Oct 20).

The achievement recognized by the 1993 Nobel Prize in Physiology or Medicine was RNA splicing, and the recipients of the prize were two men, each nominated by the labs credited with the discovery by virtue of their parallel publication (MIT and Cold Spring Harbor Laboratory). Yet neither man was the first author on his lab's key publication. This article profiles six women who contributed significantly to this prizewinning research, two of whom who were first authors and had their own research grants. One of these was Louise Chow, who was still given only second-class treatment at the 40th anniversary of the research at Cold Spring Harbor.

3. Olivia Eickerman and Moses Rifkin, "The Elephant in the (Physics Class) Room: Discussing Gender Inequality in Our Class," *Phys. Teach.*, **58**(5), 301-305 (May 20).
4. Adrienne Traxler and Jennifer Blue, "Sex and Gender as Non-binary: What Does this Mean for Physics Teachers?" *Phys. Teach.*, **58**(6), 395-397 (Sep 20).

These articles are part of a collection on "Sex, Gender, and Physics Teaching," which will appear during the remainder of 2020, following upon a similar collection on "Race and Physics Teaching" which appeared in the September, October, and December 2017 issues of the same journal. Rifkin addressed both race and gender inequity at the summer 2018 meeting of the American Association of Physics Teachers, as reported in our Fall 2018 issue. An article by Rifkin on racial inequity in physics is reference #6 below.

5. Elizabeth Hobbs, "Transgender Perspectives in the Biology Classroom," *Sci. Teach.*, **87**(7), 22-25 (Mar 20).

A teacher whose spouse became a transgender female writes about this experience as a basis for showing kindness and respect for students of all gender expressions.

6. Moses Rifkin, "Who Does Science?" *Sci. Teach.*, **87** (9), 24-31 (Jul/Aug 20).

On the premise that "biases present in American society affect the practice of science as well" and his belief that "nobody is better positioned to address the systemic imbalances in science than science teachers," physics teacher Rifkin has developed his UnderRepresentation Curriculum (URC) which "begins with a question: does the population of scientists match the population of America?" Pre- and post-testing of his students found that the URC enabled larger percentages of them able to name black physicists, feeling comfortable speaking their mind in conversations about race, and feeling that they could succeed in physics, and a smaller percentage who felt that "talking about race is bad because it keeps us from being colorblind," in accordance with a quotation from Na'ilah Suad Nasir that "to not discuss or address issues of race, culture, and inequality is to accept the current patterns of inequality and marginalization." The URL for the URC is <http://underrep.com>.

7. Susan Milius, "Florida Keys OK GM Mosquitoes," *Sci. News*, 198(5), 6 (12 Sep 20).

Of 46 varieties of mosquitoes in the Florida Keys, one of the most difficult to control is the *Aedes aegypti*, which carries dengue, Zika, and chikungunya. Weary of controlling it chemically, the Florida Keys Control District Board voted 4-1 to institute biological warfare with eggs bred to produce males whose female offspring will die. But there is a catch of concern: These males must be bred by females carrying the female-killer gene, and their own deaths are spared by adding the antibiotic tetracycline to their water. But antibiotics found in wastewater and in citrus orchard treatments could therefore spare the lives of daughters of the males bred to cause them to die.

8. Devarati Bhattacharya, Kimberly Carroll Steward, Mark Chandler, and Cory Forbes, "Using Climate Models to Learn About Global Climate Change," *Sci. Teach.*, **88**(1), 58-66 (Sep/Oct 20).

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REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Spencer R. Weart, *The Rise of Nuclear Fear* (Harvard, Cambridge, 2012). 367 pp. ISBN # 978-0-674-05233-8. $26.00 (paper).

During the summer of 1976 I had the opportunity to participate in a four-week Nuclear Science workshop for secondary school teachers at Penn State University. It was a thorough learning experience, and at the end of the workshop we toured the experimental nuclear reactor on the Penn State campus. I distinctly remember the blue glow of the water due to Čerenkov radiation in the pool. Later, when telling people about the workshop and viewing the cooling pool of the reactor, I would tell people, "I'd swim in that pool!"

A little less than three years later, the Three Mile Island reactor mishap occurred. We were about to relocate to Florida from Western New York, and despite all I had learned and understood about generating electricity using nuclear energy, I was a bit anxious about driving through the vicinity of the Three Mile Island plant.

This well-written and exhaustively researched book helped me understand the source of my anxiety. To get an idea of the research the author completed for the book, readers can view the bibliography, which includes numerous book references as well as website links. Weart introduces the potential of nuclear energy by describing the analysis of noted scientist Sir William Crookes in 1903. Long before any energy had been produced from nuclear reactions, Crookes indicated that, converted to energy, one gram of radium could be used to raise the British naval fleet to a height of several thousand feet. In a magazine article published in 1930, physicist Robert Millikan was quoted as indicating that the by-products of the research completed by spending one billion dollars to determine if atomic transmutation could be controlled would repay the expense, "and if it succeeded, (result in) a new world for man." Weart goes on to describe the widespread use of radium, and the hazards it poses.

In a chapter titled "The News from Hiroshima," Weart describes the devastation caused by the first atomic weapons, and the resulting reaction of the general public. He writes that "The feelings of horror redoubled with the news of atomic bomb disease." He next describes civil defense programs designed to protect populations during a Soviet nuclear attack. Millions of volunteers of the Federal Civil Defense Administration received instruction about the nuclear blast, resulting fire, and radiation injury resulting from the detonation of a nuclear weapon. I remember participating in "duck and cover" drills at school, with no real idea of exactly from what we were ducking and covering. Weart briefly discusses civil defense shelters that were designed and constructed. I grew up in a public housing project, with lots of families living in small apartments. In reading the information about bomb shelters, I wondered how my parents felt, knowing that there would not be a bomb shelter available for us.

There are positive aspects of energy produced from nuclear reactions. Weart writes of the doubling of demand for electricity every decade, making the vast energy that could be peacefully released from uranium very inviting. President Eisenhower's Atoms for Peace program, which was promoted as a way of managing nuclear weapon proliferation, advanced the idea that production of electrical power using nuclear technology would make electricity too cheap to meter, and result in prosperity and peace.

Analyzing the use of nuclear technology for weapons production as well as peaceful uses, Weart writes of the U.S. Atomic Energy Commission (AEC), which in the mid-1950s spent less than one tenth of its budget on civilian uses of nuclear technology. Issues the AEC dealt with such as the review of and resulting removal of Robert Oppenheimer's security clearance, and the issue of public versus private control of civilian reactors, diminished the effectiveness of the agency.

The testing of nuclear weapons, including the hydrogen (fusion) bomb, was also controversial. A test designated BRAVO in March of 1954 contaminated a Japanese fishing vessel crew with radiation, resulting in the death of a member of that crew.

The radioactive dust found in the atmosphere resulting from these tests was also a concern. This led Linus Pauling, a 1954 Nobel Prize winning chemist, to actively oppose atmospheric testing of nuclear weapons. In 1962 he was awarded for his efforts with the Nobel Peace Prize. Weart writes that in 1963, the U.S., Britain, and the U.S.S.R. signed a treaty "promising not to test nuclear weapons in the atmosphere."

Weart examines the design of nuclear reactors used to produce electricity in the U.S. and the U.S.S.R. and its satellite nations. A significant difference was the use of containment shells constructed encasing U.S. reactors, designed to prevent release of harmful radiation in the event of an accident. Soviet reactor design included no containment shell. Weart indicates this approach saved money in construction and made reactor refueling easier. He describes some of the nuclear reactor mishaps that occurred in the 1950s, as well as the Chernobyl accident

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that occurred in 1986. (Anyone interested in reading an eye-opening account of the Chernobyl disaster should get a copy of *Ablaze*, by Piers Paul Read.)

Weart includes a description of the offensive weapons developed using nuclear technology as well as the defensive weapons that were implemented. In the mid-1960s the development of the Antiballistic Missile (ABM) defense system was hotly debated. He writes that the debate over the ABM system "reminded citizens that government decisions about nuclear technology could be scientifically suspect, and politically vulnerable too." He also writes of the activities of the Union of Concerned Scientists (UCS), and the Sierra Club, which opposed expansion of nuclear power plant construction.

Analyzing the poisonous wastes produced by nuclear energy production processes compared with energy produced by burning coal, Weart notes the radioactive wastes produced in mining uranium, compared to the damage done to the environment resulting from mining and burning coal. He describes the growing opposition to uses of nuclear technology for weapons production as well as for peaceful uses. Weart writes of the Three Mile Island accident that occurred in 1979, indicating that it "provided a litmus test of how the public in general, saw reactors." The repercussions from that accident effectively ended construction of new reactors in the U.S.

Evidence is cited indicating that anxiety about nuclear war resurfaced in the early 1980s. That occurred in part due to the 9,000 nuclear weapons that had been produced by the U.S., including 2,000 designed to be carried by aircraft. At about the same time, the U.S.S.R. had produced the same number of ballistic missile nuclear weapons. Weart includes information about the debate in the U.S. over the production of the neutron bomb, capable of killing humans but leaving physical structures intact. He also notes that there was concern in the U.S. that newly elected President Ronald Reagan might well be willing to launch a nuclear war. He includes a great amount of information about Reagan's proposed Star Wars program, designed to intercept enemy-launched nuclear missiles. The brinkmanship eventually led to accommodation between the two countries.

In the early 2000s, concern about global warming due to large increases in greenhouse gases in our atmosphere led to discussions about increasing the number of nuclear power plants. The terrorist attack that occurred on 11 September 2001 increased public concern about the potential of terrorists using a nuclear weapon against a U.S. city. Weart concludes with a personal note, writing "Nuclear energy and its imagery have made familiar the dramatic possibilities for gain and loss that our own human energy can release. In the long run we may find that they have aided us toward the true transmutations we need."

This book is enjoyable to read and deeply informative about nuclear science and the effect its development has had on the general public.

- Frank Lock

(*Editor's Note*: Frank Lock is a retired high school physics teacher, Georgia State University PhysTEC teacher in residence, a Woodrow Wilson Fellows mentor, and a STEP UP ambassador.)

Graham Farmelo, *The Universe Speaks in Numbers: How Modern Math Reveals Nature's Deepest Secrets* (Basic, New York, 2019). ISBN 978-046505665-1. $30.

Years ago while reading another excellent book by this author (*The Strangest Man*, a biography of Paul Dirac), I became fascinated by a well-known photograph of Richard Feynman talking with Paul Dirac. Dirac has his back to a wall and stands face to face with an animated Feynman asking his hero a question. Dirac was well known to be terse. Feynman was a naturally talkative, native New Yorker who used slang and talked fast. The question Feynman asked Dirac in 1946 concerned an issue both men were acutely aware of at that time. It concerned the terms and mathematics of quantum field theory. If you have any interest in that along with similar topics in physics and math theory where mathematics overlaps with physical thoughts, you must read this book. It clears away much confusion by sharing obscure but relevant historical facts connecting many events from before Newton to after Hawking. Many amazing and sophisticated ideas can be found here in this well-written and highly informative book. It is a history lesson that significantly added to my understanding of many modern physics and math topics. This book is primarily about how math informs science and how science informs math to further our deepest understanding of nature. The author recounts how both highly conceptual subjects, notably advanced mathematics of all forms and theoretical physics in all areas, interact with the other to operate best in close agreement together as done in the past, is doing today, and will do tomorrow. It recounts in many examples how numerical simplification, symmetry, redundancy in representation, and the employing of correct mathematical formalism have enabled physics to push modern ideas with mathematical rigor forward.

Farmelo's first chapter, "Mathematics Drives Away the Cloud," focuses on the work of Newton. We marvel at him, the solitary and singular explorer who created differential calculus to accompany his ideas of motion and force with his theory of universal gravity. It was called universal when published; and his ideas were con-

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sidered revolutionary as well. Remember that Newton lived in a post-Copernican world. His laws accurately described mass objects moving about in a uniform space and time. But his work leaves out many important things. How did gravity reach out and affect things? Today we see his efforts as limited and incomplete with respect to deep space and time. Newton's dynamics needed more to fully describe the universe. Although his second law popularly states $F = ma$, his book actually has it that a force is a change of momentum. In that form Newton's laws can be expanded to accord with special relativity. And is the celestial mechanism in motion endlessly? Today we know there is no universal time; space when carefully examined appears to not be as flat everywhere as Euclid had proposed. A non-infinite light speed has consequences in any three-dimensional space with time. The real universe has time evolving; space open, endless in extent; bursting into existence in a past moment, and expanding now. Newton's ideas about mass and motion can get you to Mars but are less useful if dark matter and dark energy dominate a larger universe as known today. Newtonian concepts are unable to describe a real universe found beyond the solar system. Newton's ideas do not explain why galaxies hold together. Halley, who helped Newton bring the *Principia* forward, never recognized there were galaxies outside our system of planets, and in that time only six planets were known.

To develop physics with the most general explanatory ability, advanced mathematics is required to accomplish the task. Old school theories created by physicists in the past are built from the bottom up as Newton built his: 1) Define basic components, create definitions and useful explanations. 2) Utilize the rules to account for behaviors and observations known to highlight the fitness of that theoretical description. 3) Extend and predict if possible, within the rules thus established. The bulge of a rotating Earth comes to mind. That was a clear result Newton predicted. Newton's popular achievement in the minds of the day was his demonstration of the 27.3-day orbital period of the moon. He derived it by employing ratios of distances known along with his laws of force and gravity. Newton used geometry in the *Principia* rather than his differential calculus to demonstrate his profound achievement for all to see, as calculus was still unknown to his potential readers when the work was published in July 1687. It is an old school masterpiece but nearly impossible to read. The French mathematician Laplace working in France extended Newton's laws with his book *Celestial Mechanics*. But Laplace did not embrace the almighty as Newton did. The rules of math were enough for him. Laplace's imprint on physics was his use of calculus and the establishment of modern mathematical methods in physics. His fame diminished when he was unable to explain Oersted's discoveries and when Napoleon was defeated. On the continent progress continued with d'Alembert, Bernoulli, Cauchy, Euler, Fourier, and Lagrange, who together forged a common mathematical and physics pathway forward.

Different mathematical representations of a physical situation that make equivalent predictions are well known. This is shown in the second chapter, "Shining the Torch on Electricity and Magnetism." What we see today representing Maxwell's equations are different representations in differential and integral vector calculus forms. Maxwell originally set out to develop a comprehensive summary to represent all known experimental results and observations to describe charge, current, electric and magnetic effects and the associated fields using ideas Helmholtz first used to describe fluid flow. Maxwell's goal was a comprehensive unification of electric and magnetic behavior as the many experiments had already illustrated. He was impressed by Faraday's use of the 'lines of force' imagery. Maxwell knew he was on to something in 1862 when first calculating the known speed of light with the electric and magnetic constants as measured in a vacuum. His genius was to add a displacement current to Ampere's law. Maxwell showed the mathematical way to illustrate ideas concerning electric and magnetic fields; with symmetry, unification of phenomenon, and that is what really shines on. Hertz in the 1890s showed the correctness of Maxwell's four expressions experimentally. The unification of electric and magnetic behavior was complete, profound, and quite an accomplishment. The advanced math used provided the tools needed to simplify, unify, and present those ideas. Maxwell died in 1879, too soon to see any enduring acclaim of his life's work. But his *magnum opus* was seen by both Einstein and Feynman as the efforts of a theoretical genius. Maxwell used representational mathematics in a fresh application to comprehensively represent newly discovered phenomena with the goal of unifying electricity and magnetism. His creative vision and theoretical efforts paid off. As an imaginative scientist and creative mathematician, he established the basic method this book celebrates. Einstein said it took physicists "decades to grasp the full significance" of that intellectual initiative.

Sometimes different rules based on different premises can effectively describe a situation. Does light act as a wave, or is that light acts as a particle? These questions would be answered by quantum mechanics, the subject of the fourth chapter. Both descriptions of light have value when applied properly in differing situations. The lens of the eye bends light waves, and the rods and cones receive photons at the retina. But because physics uses numerical rules to describe an underlying reality, already proven mathematical forms can push representational descriptions with broad numerical foundations better than the simple rules first seen in a particular theory when first discovered from experiments. New generalized descriptions with multiple formulations provide a choice for a superior formalism that is more broadly applicable. New

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ideas spawn new mathematics, which extends theory into new ideas. Physicists play this game with mathematicians when a physical principle gets translated into a mathematical statement. The existence of the branching interconnectedness of proper mathematical languages when applied in a physical theory, each with its own, different, associated representations of the world helps us better understand and correctly advance theoretical physics best. That is another deep insight this book explains. Planck was a founding father of the new physics, and like Maxwell he knew he was on to something. But he was unsure of what that was. Steeped in classical physics, he wandered into the new century with his discovery of the quantum nature of light (and energy) mainly because of how mathematics demanded it. He was acting in a moment of desperation. Einstein, Bohr, de Broglie and many others proceeded to write out correct new rules in physics. Heisenberg employed established relationships of a non-commuting algebra. Developed math was put to work to advance quantum mechanics.

The third chapter, "Shining the Torch on Gravity Again," describes how Einstein asked others to help him understand the non-Euclidean tensor math he needed to describe curved space. G.H. Hardy said math is much like "patterns out of ideas," whereas Einstein observed that math was "the free creation of the mind." General relativity was done in just that way. Physics created the meaning and context while the mathematicians had previously established the ideas of curved space. This illustrates the basic premise of this book. Einstein wrote in 1938 of his belief in rationalism, calling mathematics the only trustworthy source of truth. In 1962 Dirac called that deep connection between physics and mathematics the way "God the mathematician" was able to bring out beautiful mathematical features to describe the real world. Can pure thought capture reality? Einstein thought so. Mathematics drives away the clouds, as Halley said of the *Principi*a. Maxwell wrote that mathematics is best capable of obtaining the correct shapes and dimensions of reality, as a useful, economical, and the most beautiful and harmonious methodology, echoing Kepler.

Chapter three recounts the moment in 1919 when Einstein called Herman Weyl's first publication of a gauge theory a "first class stroke of genius." Eleven years later Weyl correctly modified the theory to properly model an atom's history to better mimic the reality of the world. This book adds to my understanding of Emmy Noether and why she is so famous, recounting how she earned herself a Ph.D. attending classes in Erlanger. She worked for seven years without salary in mathematics. A German woman in 1900 attending the University to study mathematics faced considerable obstacles. But her brilliant efforts were soon recognized and promoted by Hilbert and Klein. They brought her to Göttingen where they shared the recent mathematics of general relativity with her. She then produced a most powerful idea of connecting mathematical symmetries to physical law. She was the first to establish the underlying connections between mathematical symmetries and the results of experiments. The voice of this world-class algebraist went silent when she passed away eighteen months after emigrating to America. She had left Germany when denied a University position and in America she had the same fate. No leading American university would offer her a position. Twelve days after Emmy Noether passed away, Weyl called her the "greatest" woman mathematician.

Traditionally, physicists are reductionists. But not Paul Dirac. He embraced the method of beautiful math and correct physics. His equation was a mathematical fusion of relativity with quantum behavior. He did not reduce the task to discovered basic principles, observations and experiments, taking measurements to write proper descriptive relationships. Inspired by Heisenberg's first paper on quantum mechanics, he used the non-commuting difference with ease. He and others were familiar with such algebra. He wrote correct math that was correct physics. His equation was mathematically tailored to describe a Lorentz-invariant free electron wave. The resulting electron wave equation mathematically and magically produced Pauli spin and antimatter as a consequence. It was 1931. In one year, electrons with a positive charge were discovered by Anderson in California. The discovery was by an experimentalist who did not know of Dirac's antielectron theory. Dirac also pointed to a vacuum full of virtual stuff. Feynman says the Lorentz-invariant electron is the condition needed to fully realize electron spin and antimatter as discovered by Dirac with his effort. No one knew antimatter was real until it was discovered, but it was implicit in the equation Dirac put forth. This book illustrates how this basic idea operates in this fashion. Dirac skillfully used mathematics to see into a new world; beautiful math invented spin and uncovered the reality of antimatter.

Chapter five documents the long divorce in the 1950s between math and physics. Dyson recounts that was the time when no help was shared and physicists thought themselves too smart to ask for assistance. Dyson knew of Gauss and Euler. Both were mathematical and physics adept. Poincaré is another one of his heroes. Dyson was able to show the ideas of renormalization were all equivalent. In this way the author highlights again the main idea of this book.

Today researchers are attempting to wean physics off of space-time in order to pave the way toward a deeper theory. Currently, to predict how particles morph and scatter when they collide in space-time, physicists use a complicated diagrammatic scheme invented by Feynman. The so-called Feynman diagrams indicate the probabili-

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ties, or "scattering amplitudes," of different particle-collision outcomes. In 2013, Nima Arkani-Hamed and Jaroslav Trnka discovered a reformulation of scattering amplitudes that makes reference to neither space nor time. They found that the amplitudes of certain particle collisions are encoded in the volume of a jewel-like geometric object, which they dubbed the amplituhedron.

This book is extensive in sharing how beautiful math and amazing physics benefit by working together. I strongly recommend it for those who enjoy beautiful physics, useful math, and the stories of the virtuosos who produce such ideas for our sharing and our appreciation. That is why I reviewed this book, and why I suggest reading it. Perhaps it is that the horizons we see are limits, and those horizons prevent thinking and feeling a new broad understanding not of the universe, but by the beauty outside us.

- Jack DePalma

(*Editor's Note*: Jack DePalma is a retired physics teacher from the New York City public schools. He is also president of the Physics Club of New York.)

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The authors describe teaching a four-week unit on global climate change using EzGCM, which they describe as a "gateway toolkit that can help high school students better understand GCC [Global Climate Change] and make sense of the major national and international climate assessments that inform and guide climate change policy." It runs on tablets and Chromebooks. The URL is <http://www.ezgcm.org>.

9. Jacob White, John A. Means, Tim Hall, and Denise Shockley, "Is This Watershed Contaminated with PCBs?" *Sci. Teach.*, **87**(8), 26-31 (Apr/May 20).

The early years of this *Newsletter* saw frequent reporting about the PCBs (polychlorinated biphenyls) discharged by General Electric into the Hudson River. This article acknowledges them as well and provides a simulation of the detection of PCBs in fish allegedly caught at various sites in a watershed. The watershed is a fictitious one designed by the teacher, and the fish are sections of frozen unseasoned and unbreaded fish, some "contaminated" with 1 M sodium hydroxide and all placed into a separate plastic bag marked with the type of fish and collection site. They are then tested by adding a few drops of phenolphthalein solution, which will cause the "contaminated" fish samples to turn "bright pink." Based upon the pattern of detection of "contaminated" fish and the type of fish, students are asked to determine where a source of simulated PCBs might lie.

10. Jaron Boerner-Mercier and Ron Gray, "Investigating Land Ethics," *Sci. Teach.*, **87**(5), 36-42 (Jan 20).

Attributing the onset of the field of land ethics to Aldo Leopold's *A Sand County Almanac*, this article describes a student symposium representing five land ethics points of view (ecological, economical, egalitarian, libertarian, and utilitarian) applied to the Grand Staircase-Escalante National Monument in southern Utah, near the authors' home base of Northern Arizona University.

Clearinghouse Update

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

Physics Today profiles Sheila Tobias

Sheila Tobias spoke at the 1992 NASTS meeting about her book, *They're Not Dumb, They're Different: Stalking the Second Tier*, in which she found that nonscience majors in college could succeed in introductory courses for science majors, and the Spring 1992 issue of this *Newsletter* both covered her talk and reviewed her book. Our Winter 2010 issue reviewed yet another of Tobias's books (this one coauthored with Anne Baffert), *Science Teaching as a Profession: What it Isn't, How it Could Be*. Now (on 11 August 2020) *Physics Today* has profiled Tobias, in an interview which traces her career as an activist on behalf of training scientists, particularly those in underrepresented categories (*i.e.,* all categories except white men). There are many qualified candidates, she has found, in these underrepresented categories, but they are in what she calls the "second tier" – rather than come to science "naturally" they need to be invited and be given encouragement. In the interview she classifies herself as a member of that second tier who might have majored in science instead of politics and history had Thomas Kuhn encouraged her after complimenting her performance in his "Structure of Scientific Revolutions" course when she was a Radcliffe freshman.

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Wildfire Dangers

by Michael J. Passow
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Globally, wildfires threaten extensive parts of the environment — developed or undeveloped. Some are deliberately or accidentally started by people — one famous case involves a "gender-reveal" party — but others begin with lightning strikes.

One the main organizations monitoring and helping to fight wildfires is the United States Geological Survey's WERC (Western Ecological Research Center, https://www.usgs.gov/centers/werc/). WERC is a USGS Ecosystems Mission Area center operating primarily in California and Nevada. Scientists based at stations in these two states study wildfire history and behavior in the Sierra Nevada forests, Mojave Desert, and chaparral ecosystems of southern California. Such research leads to practical applications in preparing for, preventing, and fighting wildfires and preserving threatened ecosystems. In addition to wildfires, WERC scientists are studying sage-grouse, impacts on marine populations of dredging San Francisco Bay, fledgling seabirds in Hawaii, and longevity of influenza A viruses in wetlands.

One of the leading academic investigators of wild fires is Dr. A. Park Williams of the Lamont-Doherty Earth Observatory of Columbia University (https://www.aparkwilliams.com/). He describes himself as a hydroclimatologist, focusing on the droughts of the western U.S. Williams recently gave a video talk to more than a thousand people describing the current and past wildfires in the continental U.S. He mentioned the now-famous comments of some social media claims that wildfires stopped at the border. The truth, of course, is that the maps only show U.S. data, just as weather maps on TV only show U.S. data. Canada has its own wildfire and weather monitoring systems that pick up the story north of the border.

Williams also explained that there is a constant tension between the desire of people to live within zones that have been wildfire locations and the threat of new fires when conditions are ripe. He is part of the Lamont Tree Ring Lab Group (https://www.ldeo.columbia.edu/tree-ring-laboratory). He also notes that

> "Western North America has seen near-persistent drought since the year 2000. We used climate observations, tree-ring records, land-surface modeling, and climate model simulations to find that human-caused warming put an otherwise moderate drought onto a megadrought trajectory in the first 2 decades of the 21st century. Tree rings tell us that natural climate variability will continue to cause wild swings in western North American water availability. Climate models project that over the long term, drying baseline conditions will make it increasingly easy to slide into severe drought and increasingly difficult to emerge from severe drought."

Climate change seems to be creating drier zones in much of the western U.S. Therefore, like death and taxes, we will always have wildfires with us. When we build homes and towns in places where wildfires naturally occur, especially during periods of drought, the danger of loss of property and life increases. Those of us who live in urban or suburban areas pay little attention to such threats, just as most of us do not see any immediate danger from sea level rise. Natural events, however, do not operate on the same time scale as human activities, so it may be wise to start paying more attention to wildfires.