TEACHERS CLEARINGHOUSE
FOR SCIENCE AND SOCIETY EDUCATION
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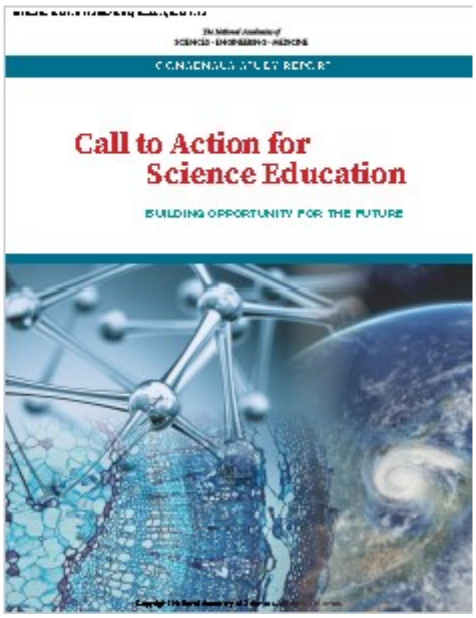
Call to Action Calls for Equity in Science Ed

The Carnegie Corporation of New York has called for *yet another* report on U.S. science education. They requested that "The National Academies of Sciences, Engineering, and Medicine will appoint an *ad hoc* committee to author a national call to action to advance science education programs and instruction in K-12 and postsecondary institutions in ways that will prepare students to face the global challenges of the future both as engaged participants in society and as future STEM professionals." (p. 12) Many of the specific charges to the committee call for things that have appeared in previous reports on U.S. science education, but three of them are different and particularly worthy of note: 1) "identify major challenges for implementing coherent science education K-16"; 2) "discuss how science relates to the other STEM disciplines in K-16"; 3) "identify areas where more information is needed . . . ." (p. 12)



The report produced by the Committee, chaired by New York Hall of Science President Margaret Honey, is titled *Call to Action for Science Education: Building Opportunity for the Future*. The quotation accompanying its frontispiece states that "Scientific thinking and understanding are essential for all people navigating the world, not just for scientists and other science, technology, engineering, and mathematics (STEM) professionals." It is also the second sentence of the Summary, which begins with an even grander statement: "Science is an essential tool for solving the greatest problems of our time and understanding the world around us." (p.7) Yet, the Summary continues with the more somber statement, which also appears in the report's Introduction, "science education is not the natural priority it needs to be." (pp. 7, 11)

In addition to investigating the items they were charged to look into, the Committee also looked into inequities in U.S. science education. This results in the profuse use of the phrase "**better, more equitable science education**." Everywhere it appears in the report it is highlighted in cyan, and it will be highlighted in boldface in this article. It shows up in the first section to follow the Introduction: "Why **Better, More Equitable Science Education** Should be a National Priority." Repeating the statement accompanying the frontispiece, this section points out that "Believing that science is for scientists only" is "a big mistake." "Science should be taught with all people in mind." (p. 14) It goes on to argue that science is as much a foundational skill as reading, writing, and math. "People need scientific literacy to be critical consumers . . . of information," (p. 15) as can be seen by public reaction to information related to the pandemic; but it "does not replace values, ethics, faith, and aesthetics." (p. 15) "Science . . . must be for all, not only for reasons of fairness and equity, but also so that a democratic society can deal with the problems that confront it." (p. 15)

This section also acknowledges that science is also essential to join the STEM workforce, where the 2019 average wage of $86,980 was almost $50,000 greater than the average wage of $38,160 in the rest of the workforce. It points out that the opportunity to join the STEM workforce should be more equitably distributed, though: people of color comprise 27% of U.S. population, the report states, but only 11% of the STEM workforce. "Diversity in the workplace, particularly the STEM workforce, also improves work performance and engagement, enhances the quality of research . . ., and supports innovation and growth," the report continues. "Science must not remain a club for the few." (p. 18) The report adds that in educating people for the STEM workforce, science should not receive short shrift, because "science is foundational to technology and engineering and pro-

(continued on page 18)

<u>Commentary:</u> Removing Inequity from Science Education

The threat of global climate change has been hanging over our heads since before this *Newsletter* was first published in 1982. Yet, not until my commentary in our Spring 2021 issue did I feel that I could say that I saw sufficient concern that I could see a path toward doing something meaningful about it.

Much the same is true about inequity in American science education. Every time I've written a report on *Science and Engineering Indicators* I've written about gaps in science test scores and science degrees awarded – between Black and Latinx students on one hand and white students on the other – because Blacks and Latinx students were taught in less well-equipped schools by less-experienced teachers, who either stayed in teaching only for a short time or longed for the day an opportunity to teach in a better-equipped suburban school came up. This has been a problem as old as American education itself.

Three things I experienced the past summer now give me hope that inequity in American science education is a problem about which it is acknowledged *that we must do something*, and each is addressed in a separate article in this issue. The first was at the institutional level, learning about the SEA Change (with "SEA" being an acronym for <u>S</u>TEMM <u>E</u>quity <u>A</u>chievement) program which seeks to make diversity, equity, and inclusion the norm of the STEMM community, as explained by Shirley Malcom of the American Association for the Advancement of Science and Beth Cunningham of the American Association of Physics Teachers (AAPT) at the 2021 AAPT summer meeting.

Secondly, at the national level I read *Call to Action for Science Education: Building Opportunity for the Future*, and was impressed that the committee writing this document had overtly gone beyond its original charge to address inequity in American science education – by its profuse use of the phrase "**better, more equitable science education**."

Noble as these organized efforts are, I think I was most touched by the Keynote Address at IBM's Quantum Educator Summit by Chandralekha Singh of the University of Pittsburgh, who considered inequity in American science education at the level of the individual teacher. We need to make the Black and Latinx students in our classroom feel welcome and give them a sense of belonging, she stressed, so that their achievements can narrow the aforementioned gaps. Otherwise, she said, those gaps will only get worse.

I plan to share what Singh said in my classes this fall, and I hope that by doing so I can also bolster the organizational efforts described above. Bill Gates wrote that dealing with climate change would be hard, but removing inequity from American science education will be harder. Dealing with climate change will require us to make changes in the way we live in terms of creature comforts, but dealing with inequity in science education will require us to think, feel, and care about each other. It has correctly been said that each journey, no matter how difficult, begins with the first step. What I have experienced this summer has shown me the first step I must take, and I am going to take it.

\- John L. Roeder

IN THIS ISSUE

PolS-T Conference, p. 3
EPIC, p. 6
Etkina, p. 8
From "Techno" to "Socio," p. 9
SEA Change, p. 10
Beyond Physics, p. 10
Quantum Ed Summit, p. 11
Back to the Moon, p 14
Advanced Manufacturing, p. 15
Hauser on the Egg, p. 16
Resources, p. 19
Reviews, p. 20
Clearinghouse Update, p. 26
Eunice Foote, p. 26
Passow on Climate Sch, p. 27
IPCC, p. 28

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>.

PoLS-T stages second physics education conference

It's safe to say that in the community of physics educators, Professor Eric Mazur of Harvard University has achieved legendary status. His most recent achievement has been to create PoLS-T, the Physics of Living Systems Teacher Network, which is funded by the National Science Foundation as part of its Physics of Living Systems program. PoLS-T – "of high school physics teachers, for high school physics teachers, and by high school physics teachers" – invites noted physics educators to make online presentations to be viewed on Perusall by physics teachers who then attend a livestreamed Q & A conducted in real time by the presenter on selected Saturday mornings; and presents multiday online conferences. The second such annual conference, billed as PoLS-T Exchange: "Building a Global Network of High School Physics Teachers," was held from 29 June through 1 July 2021.

The "assignment" for each conferee prior to each day's events was to watch between five and eight "talks" on videos ranging between 10 and 20 minutes, just like the video presentations to be watched in advance of the Saturday morning Q & A sessions. The first hour of each conference day was devoted to an invited keynote speaker, whose presentation was streamed live or presented in prerecorded form and followed by a livestreamed Q & A. The second hour of the conference day featured a livestreamed panel discussion by those whose talks had been assigned to be viewed in advance, in which participants could ask questions about the talks. After the first two hours, which were conducted on Zoom, the conference moved to a session on a different platform, Spatial.Chat, in which participants and presenters could gather in groups of their own choice for conversations.

Bailey highlights what physics graduates can do

Each day of the PoLS-T Exchange had a theme, and the theme for 29 June was "Why Physics?" The keynote speaker for this theme, speaking on "Physics for Tomorrow – Empowering Physics Students to Change the World," was Crystal Bailey, Head of Career Programs for the American Physical Society (APS), who began her pitch to make physics a more attractive subject by showing a set of Google images of scientists. She noted three frequent features – Einstein, the atom, and a lab coat – all showing white men pursuing knowledge, viewed as an elite group doing hard things. Bailey countered that physics should be striving for diversity, to be more welcoming to all students and therefore strengthen our discipline.

Bailey went on to state that physics should present itself as providing well-paying, stable, rewarding careers – with the possibility of making a positive social impact. Making a positive social impact, in fact, was regarded as important by 92% of the physics undergraduates surveyed by APS's PIPELINE Network, she said. Another thing that prospective physics majors don't always realize, Bailey observed, is that most physics graduates with a bachelor's degree are not employed in academia. They usually don't have "physicist" in their job title and often work in interdisciplinary teams. Physics graduates with a master's degree might manage these teams, and graduates with both bachelor's and master's degrees also work in the National Laboratories. Graduates with doctorates also work in these labs as well as in the private sector and are well paid.

Why are graduates with physics degrees of interest to employers? Bailey listed four elements of the curriculum for physics major – programming, circuit design, math proficiency, and fabrication – that make graduates attractive candidates to hire for positions that have testing and analysis, development and design, and running queries and reports in their job description and words like analyst, engineer, and developer in their job titles. They also complement engineers and have such other attractive capabilities as being able to grasp concepts, identify and solve problems, analyze data, and follow through to get additional answers that they need, according to 80% of surveyed employers. Additionally, physics curricular work in making models has proved transferable to other fields like insurance.

Other developments can make the physics graduate more employable. Shifting from a techno-centered to a human-centered approach can enable physics to attract a broader audience. This was included in the goals of the aforementioned PIPELINE Network, whose goal is to develop physics curricula which integrate technical skills and problem solving, encourage teamwork and open-ended thinking, develop communication with diverse stakeholders, contextualize physics in real-world applications, develop critical professional life skills, and emphasize the potential for social impact. This was branded as Physics Innovation and Entrepreneurship (PIE) education, but Bailey acknowledged that there was a lot of pushback on the choice of the word, "entrepreneurship."

Examples have included teaching kinematics at Loyola University of Maryland via the Elon Musk Hyperloop transport concept. Another is "Pop-Up" courses, which facilitate education about all sorts of new developments at the Rochester Institute of Technology. And George Washington University has instituted a Communications Capstone. These are among the developments profiled in the recent APS publication, *Educating Physicists for Impactful Careers* (which can be accessed online at <epic.aps.org>). Lastly, Bailey cited interest in developing the quantum workforce. The APS has become part of the Q12 Partnership for Quantum Workforce Development and there will be a Quantum "Town Hall" at the

(continued on page 4)

PoLS-T conference

(continued from page 3)

summer meeting of the American Association of Physics. There will also be a "Quantum Crossing" in October 2021 (information is available at <q12education.org>).

Gillespie shows how Everyone can be a Physicist

The theme for 30 June was "Everyone is a Physicist!" To make this point in actuality, the conference invited Latasha Gillespie, Executive Head of Global Diversity, Equity, and Inclusion (DEI) at Amazon Studios, Prime Video, and IMDb, to address the theme of the day. Gillespie began by observing that as a fundamental science, physics is important in all our lives. We are also all born curious about how the world works and how the universe is organized. This curiosity transcends race, gender, and all the other classifications used to group humans. But, she wondered, why are physicists disproportionately white men? Why aren't women, Black, Hispanic, and Native American students not seeing physics as a viable educational path and career option?

Gillespie then added that it's much the same in her industry, which is characterized by storytelling. Just as curiosity would make everyone a physicist, she noted that everyone is also a story teller. But the "gate keeping" system in Hollywood has made it harder for some to break through than others. The film and television industry is dominated by while cisgendered males, who decide which stories are told, or "greenlighted," the term used to express approval for something in her industry. Then Gillespie pointed out that teachers have the ability to greenlight students to succeed in physics; they are the first responders in this pandemic of lack of representation in physics. "If everyone is a physicist and a story teller, why isn't that reflected in the world today?" she asked.

Gillespie focused on four suggestions she had for her audience of physics teachers:

1) *Don't judge by the "first thought" you might have about a student*. It's important to take time to get to know the student.

2) *Understand that language matters*. An unexpected success should be respected for the success that it is and not viewed as an "anomaly."

3) *Consider risk* vs. *distance traveled*. Students who have persevered through adversity have "traveled farther" and should be rewarded. Familiarity should not be disproportionately favored.

4) *Consider equity* vs. *equality*. Students should be rewarded by how far they have had to travel. "Sometimes it's lonely being the 'only.'"

If we take these four things into account, Gillespie concluded, we can all be story tellers and physicists.

Some interesting points brought up in the ensuing Q & A were the following: The most critical factor to assure DEI in education is assessment. Gillespie questioned whether we are using the most appropriate evaluative proxies. She requires a statement that DEI requirements have been met for every project in order for it to be greenlighted. At least 30% diversity in a group makes no one the "only" and all to feel included.

Bergmann advocates Flipped Mastery Learning

The keynote speaker addressing the theme of "Best Teaching Practices" on 1 July was Jon Bergmann, a pioneer in developing the idea of the "flipped" classroom, in which students are asked to watch the presentation of content in prerecorded videos before class, so that they can spend their class time working with each other and with their teacher to solidify their understanding. Speaking on "Rethinking Physics Education – How Flipped and Mastery Learning Can Help Us Post-Pandemic?" Bergmann asked his audience to imagine a group of students with a wide range of abilities and new students added to a class roster midyear – or a group of students with varying "learning loss" from 2020-2021. He listed Benjamin Bloom's levels of learning, ranging from "remembering" through "understanding" "applying," "analyzing," and "evaluating" to "creating," and cited Bloom's quest for improvement in learning two standard deviations above that of conventional teaching ("two sigmas"). Bergmann's "answer" to this quest was to combine the flipped classroom with "mastery" learning, in which he'd transform the shape associated with Bloom's levels of learning from a triangle to a diamond.

Bergmann went on to list and describe "eleven pillars of flipped mastery learning": 1) no whole class instruction, 2) flexible pace, 3) extreme differentiation, 4) teacher-student interaction, 5) collaborative student work, 6) formative assessment (retaken until score is at least 80%), 7) summative assessment (retaken until score is at least 80%), 8) thousands of versions (of tests to allow multiple retakes, from a learning management system which creates them from a question database), 9) immediate feedback, 10) gamification, and 11) relationship-centering.

COVID, Bergmann pointed out, has been an opportunity to rethink *how* we teach. No longer will students tolerate boring lectures. Passive learning must give way to active.

The following points emerged from the following Q & A. To accommodate slow-paced students, place less-essential units last. The two most important factors to foster learning are active learning and relationships.

(continued on page 7)

Reynolds recommends aims for physics education

One of the "talks" to be watched prior to 29 June 2021, the first day of the PoLS-T conference, was given by Helen Reynolds of the Gregory School in Tuscon, AZ. In keeping with the day's theme of "Why Physics?" it was titled "What is Physics For?"

Reynolds began by listing three aims for what she regarded as excellent education in physics: 1) to be able to challenge ideas and debate, based on physics knowledge; 2) to be able to interrogate data and how they're presented; and 3) to know enough to know how to find out more. Although only a small percentage of our students (0.5%) will become future physicists, they *all* will become future citizens. Reynolds felt that the curriculum for both should be the same – that all should be able to do things "useful for a university education in physics," and also be able to contribute to important debates, understand the cultural impact of physics, and have a healthy level of skepticism.

To do this, Reynolds felt they would need information about *things*, such as matter, forces, energy, and electricity and magnetism, and information about *issues*, such as radiation, waves, the electromagnetic spectrum, communications, radioactivity and its effects, and energy resources. They would also need to analyze data, have a sense of size and scale (including order of magnitude estimates and back-of-the-envelope calculations), be able to make models, and be able to make a coherent case in a scientifically-based argument. A desirable physics education, she concluded, prepares students both to be future citizens and to be able to do further study. To achieve this, she advocates giving students the *big picture* of physics (which she does in her

(continued on page 7)

Johnson shares experience teaching about diversity

The theme of the second day of the PoLS-T conference, 30 June 2021, was "Everyone is a Physicist!" and one of the "talks" to be viewed prior to then was given by Jolene Johnson on her experience "Explicitly Teaching about issues of Diversity in a High School STEM Class." Johnson was teaching classes in AP Computer Science, "How to Make Almost Anything," and Project Lead The Way (described in our Fall 2001 issue) at Spring Lake Park High School (in a suburb north of Minneapolis (MN)), and she was motivated to teach a unit on diversity by the STEP UP project that aims to increase the number of women pursuing physics degrees and careers (described in our Fall 2020 issue), lack of gains of minority enrollments in physics, George Floyd's murder, and Chief Justice Roberts's asking "What unique perspective does a minority student bring to a physics class?" (described in our Winter/Spring 2016 issue). Although the school is 43% minority, her classes had a lower percentage of minority students.

The unit she intended was to last two weeks and include who does physics, with statistics on the number of women and underrepresented minorities, social science research on diversity and discrimination, the Chief Justice's question, watching "Jim Crow of the North" (a locally produced documentary), student research on STEM courses offered inside and outside redlined areas, and a final essay on diversity in physics. After a meeting with the school principal and "curriculum lead," the following ground rules were set, based upon the school culture, which included students with "blue lives matter" stickers on their cars: there would be no parent permissions slips (thus circumventing objection to "critical race theory"),

(continued on page 7)

Morey presents the Patterns Approach to sci ed

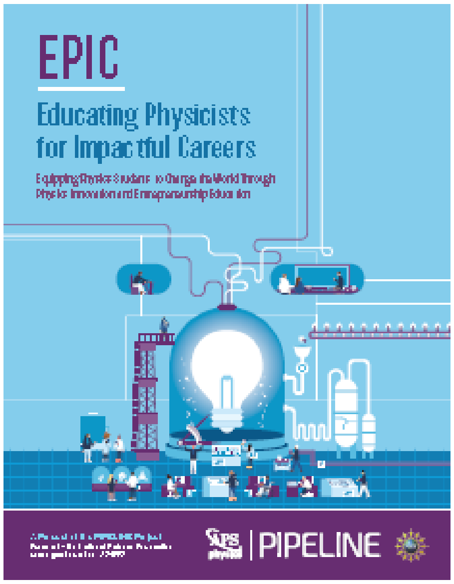
The theme of the third day of the PoLS-T conference, 30 June 2021, was "Best Teaching Practices" and one of the "talks" to be viewed prior to then was given by Shannon Morey on "The Patterns Approach: Developing Student Understanding of Mathematical Patterns in Physics through Inquiry and Project Based Learning," based on her using this approach with ninth graders at the Abbot Lawrence Academy in Lawrence, MA. Developed by Bradford Hill in Beaverton, OR, the Patterns Approach is based on eight design principles: 1) learning is student-centered, 2) science is a collaborative process, 3) science uses inquiry to discover and make sense of patterns, 4) science and engineering are interdependent, 5) teaching and learning should be culturally responsive, 6) learning is equitable and differentiated, 7) science learning is a language-rich experience, and 8) assessment and feedback are integral parts of learning. Morey focused her presentation on principle #3, for which she listed four substeps: a) make a guess based on observation, b) gather data to determine a pattern, c) make sense of the pattern through consensus, d) make a data-informed prediction and compare it with the original guess.

The website for the Patterns Approach is <http://patternsapproach.org>, and there one can see that "Patterns Physics" consists of seven units: 1) Patterns & Inquiry, 2) Texting & Driving, 3) Energy & Engineering, 4) Engineer a Shoe, 5) Waves & Technology, 6) Electricity, Power Production, and Climate Science, 7) Space & the Universe. These units typically conclude with a culminating activity that is reminiscent of the end-of-chapter challenge in the "Active Physics" curriculum. For example, students are expected to code their

(continued on page 7)

EPIC suggests epic change in physics education

When Crystal Bailey of the American Physical Society (APS) addressed the PoLS-T Exchange on 29 June 2021, she spoke of infusing physics education with innovation and entrepreneurship to make physics graduates more employable. She cited examples of what has been branded as Physics Innovation and Entrepreneurship (PIE) education from a recent APS publication, *Educating Physicists for Impactful Careers*, acronymed *EPIC*.



The full title of this publication is *Educating Physicists for Impactful Careers: Equipping Physics Students to Change the World Through Physics Innovation and Entrepreneurship Education*, and it is the product of the PIPELINE Network of institutions "to create and document new approaches to teaching innovation and entrepreneurship in physics" (the APS, Rochester Institute of Technology (RIT), Carthage College, University of Colorado-Denver, George Washington University (GWU), College of William and Mary, Loyola University of Maryland, Wright State University (OH), and Worcester Polytechnic Institute). This network resulted from a meeting of those who believed that physics graduates would be more valuable in the workforce if provided "I&E" (innovation and entrepreneurship) education at the March 2012 APS meeting in Boston. "PIPELINE also benefited from other efforts 'to transform physics education, most significantly the Joint Task Force on Undergraduate Physics Programs' and its *Phys21* report on the demands and expectations of physics programs for career success in the 21st century." (p. 4) PIPELINE itself is another acronym – Pathways to Innovation & Physics Entrepreneurship: Launching INstitutional Engagement.

The Executive Summary of *EPIC* extols the values of PIE education for the following reasons:

- "better prepares students for 21st century careers"
- "makes the discipline more attractive to potential students, sustaining and increasing enrollment"
- "connects physics and social impact that is attractive to students and prepares them to leverage their physics training in diverse careers"
- "supports the strategic goals of societies and industry"

The first part of *EPIC* (Introduction and Overview) argues that physics education, infused with innovation and entrepreneurship, is the best preparation for the "new and challenging world problems to solve, job flexibility, multiple employers, a gig economy, new demographics in the U.S., and international competition for everything" that have come to characterize the 21st century (p. 3). "Innovation and entrepreneurship encompasses . . . creativity and design thinking, . . . managing projects and diverse teams under constrained resources, a multidisciplinary and flexible approach to problem solving, learning and applying new technical skills, and communicating with diverse and nontechnical audiences." (p. 3)

But the second part (titled "Why Now, and Why This?") makes it clear that physics as a discipline isn't there yet. "[The] perception of physics as a discipline contrasts with the needs and interests of incoming college students, who are often attracted to disciplines that they can clearly connect to jobs that pay well and have an impact on their communities and the world," *EPIC* states. (p. 9) This perception of physics is supported by a survey of industrial employers, who agreed that physics majors were skilled at learning new material, identifying and solving problems, and analyzing data but *not* at designing new systems or processes, working on multidisciplinary teams, leadership, and communication. *EPIC* goes on to note that while the number of Blacks in the college application pool is projected to remain constant, that of whites is declining, and the number of Latinx applicants "is expected to increase by nearly 50% over the next decade." (p. 8) In view of higher costs for college tuition, room, and board, it is not surprising that this changing applicant pool would want their investment to lead to meaningful employment.

Because "physicists are at the core of the development of new and fundamental technologies," "physics is uniquely positioned to become a leader in the transformation of student development and preparation for the future" *EPIC* continues. (p. 8) "Physics, reimagined as PIE," (by adding innovation and entrepreneurship) "will also be attractive to the diverse population of incoming students who currently flock to other disciplines," it asserts, (p. 12) noting that such greater attraction of physics would also benefit physics departments and the institutions that house them.

The third part (titled "Physics Departments and Faculty Can Do This – But How?") points out that "There is no one "right way" to bring PIE to students." (p.18) Rather, it lists a host of ways to infuse I&E into physics educa-

(continued on page 7)

EPIC

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tion. First, there are formal courses, both in the physics department and in other departments (chemistry and industry are cited, but the communications skills course at GWU might be from their English department). It's also pointed out that how the course is taught and the degree to which it focuses on real-world situations makes a difference (RIT's "Pop-Up" courses and Loyola University's teaching kinematics in terms of Elon Musk's Hyperloop that Bailey cited in addressing the PoLS-T Exchange are cited). Other ways to infuse I&E include internships, research and projects (William and Mary conducted an activity simulating project management), and conferences.

Barriers to implementing PIE are acknowledged: insufficient knowledge about nonacademic careers, insufficient recognition or interest among colleagues, an already-full curriculum, and insufficient connection to the private sector (which can be addressed through the alumni office). PIPELINE sees PIE as building on the skills called for in *Phys21*. To scientific and technical skills, workplace skills, communication skills, and physics-specific knowledge called for in *Phys21* PIE would add entrepreneurial mindset, design thinking, business models, creativity, resources, funding, and intellectual property.

The fourth part addresses "Professional Societies, Funders, and Industry Should Support PIE – But How?" *EPIC* calls on physics education societies to promote PIE to 1) their members, at meetings, to enable them to practice it and promote it to others; to 2) their funders, to make physics look more attractive; and 3) the public, for the same reason. Economic development organizations can link educational institutions and funders, and direct funders are essential for implementation of PIE. And Industry can support PIE by providing student internships and opportunities for student research.

Among the "Resources and Opportunities" addressed in the fifth part are the annual conferences held by VentureWell, the U.S. Association for Small Business and entrepreneurship, and the American Society for Engineering Education (because many positions are filled interchangeably by physicists and engineers); the resources being assembled by PIPELINE (with the goal of building an entire curriculum); and the *Careers2020* report from the American Institute of Physics/APS.

EPIC can be accessed online at <epic.aps.org/assets/downloads/EPIC_Report_Digital.pdf>. Bailey and Douglas Arion also wrote about PIE in "Teaching physics for tomorrow: Equipping students to change the world," *Phys. Today*, **72**(10), 40-46 (Oct 19).

PoLS-T conference

(continued from page 4)

When asked the goal of physics education, Bergmann responded "the wonder of the natural world."

The proceedings of all three days of the conference can be viewed on the PoLS-T YouTube channel. The link is <https://www.youtube.com/channel/UCRzn7nZ4f8JksXXUTrouSZg/videos>.

If you would like to join the PoLS-T Network, the link to do so is <https://docs.google.com/forms/d/e/1FAIpQLScOSNatVc_zmDjyqXddKyqthYXRbs-fufpRHLX0vBWLCYptFA/viewform>.

Reynolds

(continued from page 5)

classroom with a big flow cart of her course) and showing the relevance of physics to what's going on in the world.

Johnson

(continued from page 5)

the unit would be moved to the end of the year, and it would be limited to presenting on the facts, with students left to draw their own conclusions.

In the actual presentation, the part on women in physics was presented mostly as planned, but the part on diversity was shortened and included no connection to local issues and contained less focus on explicit discrimination. Johnson summed up the student reaction by saying that most of the students were white males who didn't see the need to increase the number of minorities in physics; and, although the minority students were quiet in class, they wrote thoughtful essays.

Morey

(continued from page 5)

design for a bungee jump at the end of unit #3 and to develop a 50-year energy plan at the end of unit #6.

Just as the "Active Physics" and the Modeling approaches to teaching physics have since been applied to the teaching of chemistry and biology, the same is true for the Patterns Approach. The website lists eight units for "Patterns Chemistry" and six units for "Patterns Biology." "Patterns Chemistry" consists of 1) Kinetic Molecular Theory and Climate Change, 2) Atomic Structure and the Periodic Table, 3) Nuclear Chemistry, 4) Bonding and Intermolecular Forces, 5) Chemical Reactions, 6) Stoichiometry, 7) Thermochemistry, and 8) Rates and Equilibrium. "Patterns Biology" consists of 1) "Ecosystems and Biodiversity," 2) "Biomolecules," 3) "Cells to Organisms," 4) "Genomics," 5) "Evolution," 6) "Ecosystem Matter & Energy."

Etkina educates PoLS-T about ISLE

The featured presenter at the 19 June 2021 program of the PoLS-T (Physics Of Living Systems Teacher Network) organized by Professor Eric Mazur of Harvard University was Eugenia Etkina, Professor of Physics Education at Rutgers University and developer of the ISLE (Investigative Science Learning Environment) method of learning. Following a "flipped classroom" protocol, participants were asked in advance to watch on Perusall the video which Etkina had prepared, "When Learning Physics Mirrors Doing Physics."

Etkina opened her video by observing that since dirt looks like chocolate, a young child can be tempted to taste a sample of it to test his/her expectation. Likewise, she continued, in order to achieve feats of skill people are willing to try and fail repeatedly, test ideas experimentally, and persevered. Why, she asked, don't they do this in our classrooms?

Etkina expressed her feeling that even reformed teaching goes against what we know helps learning. Giving answers before questions arise, for example, eliminates the need to know the answers. Not allowing students to improve their work doesn't allow them to fail. Pacing curricula doesn't allow students to learn at their own pace. And grading on a curve discourages collaboration.

Etkina lamented that we teach physics as religion (as ultimate truth that students can see in the lab) but do it as science (as something we're still trying to figure out). For example, she suggested popping a balloon and asking where the sound comes from. To test that it comes from air, pop a balloon filled with water. There is less sound, but that is not enough to disprove the hypothesis. Replacing the blown-up balloon with a blown up plastic bag shows no sound when it is popped. Could it be the rubber? Subsequent tests show that the sound depends on the rate at which the air comes out of the bag/balloon.

This sequence of events is typical of what Etkina employs in her ISLE method. Observational experiments are done to identify patterns. Explanation of the patterns leads to further predictions which are tested. If the tests don't confirm the hypothesized explanation, another one must be tested. Etkina emphasized that ISLE employs an *intentional* approach, based on how students learn (by practicing) and how they feel about learning (developing confidence and a growth mindset).

The above example is only one of many to which ISLE is applicable. In our Winter/Spring 2019 issue you can read about her presentation of determining the reason for moisture on the outside of a glass of ice cold water at the spring 2019 meeting of the Southeast Pennsylvania Section of the American Association of Physics Teachers. She presented still another in her video: the effect of electromagnetic radiation on an electroscope atop which a sample of zinc has been placed. If the electroscope is negatively charged, nothing happens when visible light shines on it, but the electroscope discharges when the zinc is exposed to ultraviolet light. One hypothesis could be that ultraviolet light ionizes air around the zinc. But that is disproved when the electroscope is charged positively, and neither visible nor ultraviolet light discharges it. This sequence of events enables students to learn the photoelectric effect the way physicists originally did.

Etkina closed her video noting that because learning is a social process students should work in groups. And because a student's mindset determines the learning process, students should have the opportunity to improve their work.

Eric Mazur opened the livestreamed event on 19 June by asking where is the ideal balance of content *vs.* process in science education. Etkina responded that it depends on the goal. How many students will become physicists, she asked. In her opinion the most reasonable goal would be to get students to *think like physicists*. They learn to skateboard, bicycle, play video games, and operate cell phones without formal education. We can *build their confidence to learn* by developing their *ability to read scientific texts*.

The following Q & A ensued:

Drew Rosen: How did you deal with the pandemic?
Etkina: We recorded labs that students usually do and developed an online learning guide.
Maqseda Afroz: What are assessments like in ISLE?
Etkina: We spend several weeks training students in designing experiments and assess them according to a rubric. Allowing students to improve makes them less concerned about their grade.
Michelle McSwigan: How do you handle the resubmissions?
Etkina: A doctor doesn't stop with a diagnosis. Like doctors, who want to make patients feel better, we should help students to learn.
Joe Kremer: How do the rubrics evolve with grade level?
Etkina: They evolve to require higher level learning.
Maya Lerner: How do you introduce ISLE?
Etkina: Give students an introductory activity to answer a question based on evidence.
Elissa Levy: How can teachers of other sciences use ISLE?
Etkina: It can be done – Lehigh has used it for philosophy.

Bill Doerge made a comment on using ISLE to teach AP Physics with the text which Etkina has coauthored with Gorazd Paninsic and Alan Van Heuvelin, *College*

(continued on page 9)

Shifting from "Techno" to "Socio"

by John L. Roeder

When I started teaching physics in the late 1960s, the clamor was for science to be relevant. A decade later came a call to infuse societal topics into science courses, and the Teachers Clearinghouse for Science and Society Education was founded. "Science and Society" gave way to "Science, Technology, and Society," which has since receded from its onetime prominence, and now the concept that science should have a social impact is coming forth.

Crystal Bailey of the American Physical Society spoke of shifting from a techno-centered to a human-centered approach at the PoLS-T Exchange: "Building a Global Network of High School Physics Teachers," which was held from 29 June through 1 July 2021 (see separate story on page 3), and she made the same pitch at the summer 2021 meeting of the American Association of Physics Teachers (AAPT) on 31 July. Bailey acknowledged that this meant broadening the scope of why we do physics beyond the discovery of new knowledge.

In addressing the PoLS-T Exchange, Bailey referred to teaching kinematics at Loyola University of Maryland via the Elon Musk Hyperloop transport concept. At the AAPT summer 2021 meeting Bahram Roughani from Loyola spoke about doing this himself. Roughani noted that the number of physics bachelor's degrees is increasing but the percentage of physics degrees in STEM is decreasing. He argued for a paradigm shift from a "technocentric" to what he called a "sociotechnical" approach that can contextualize physics in real-world applications and highlight its social impact. His proposed framework to do this is to add the dimension of *why* as well as *what* and thereby include social and human impact. "Robots don't need to be inspired, but people do," he said. We need to increase the overlap between what is important to learn and what interests students.

Also addressing this idea at the AAPT summer meeting in his talk on "Updating the Curriculum with Social Context and Practical Application" was Walter Freeman of the University of Syracuse. Freeman began by observing that technocentric physics is what physicists have regarded as the basis of the scientific enterprise. But, he continued, more than this physics is part of the *human* enterprise. Instead of viewing physics at the base of a pyramid, it can also be viewed at the center of a circle, radiating outward to other disciplines, which it enables, leading to human advancement, providing a "more humanistic view of the role of physics." We could strengthen our outreach to engineering, Freeman said, by teaching physics students more about machines, some of which they will use. Beyond this is the manufacture of things people use, which entails economic and entrepreneurial skills. The end product, he emphasized, is physics in the service of humankind. This perceived role of physics can help both STEM majors and non-STEM majors alike to appreciate it.

Ben Zwickl, speaking at the meeting on "Integrating computation, experimentation, projects, and human-centered applications in lab courses," expressed surprise that only one response from 150 college physics majors why a high school student should study physics related to improving society or community. He spoke of including a DIY pulse monitor into his electronics lab course and reported that students built them and measured their pulses.

The presentation by Cassandra Croft of Portland State University on "Using Deliberative Democracy to Develop Scientific Skills through Group Collaboration" in earlier years could have been the description of a set of STS modules. Croft characterized "deliberative democracy" as integrating effective communication and collaboration with competent application to provide student-centered collaborative engagement to achieve positive perceptions of applications of science to real-world problems and enhance scientific literacy. To achieve this, she said, students need to develop such skills as applying scientific knowledge, collaborating, critical thinking, and communicating, and modules have been prepared to do this. The modules she described were prepared with the need to develop these skills in mind. They ask students to read scientific papers on physics concepts related to topics of everyday-life concern, and to respond by answering either specific questions or guiding questions. The physics concepts covered and the related every-day life concepts are listed as follows:

Physics concept	Topic
Force, momentum	Soccer headers
Circuits, EM fields	High voltage power lines
Electrostatics, fluid dynamics	Masks
Thermodynamics	Greenhouse effect
Waves, sound	Stethescopes, ultrasound devices

Etkina

(continued from page 8)

Physics: Explore and Apply. Mazur added that the high stakes of the AP test are diametrically opposed to ISLE. Etkina rejoined that AP Physics 1 and 2 are an improvement over the course they replaced, and that problems to help pass the AP test have been added to the textbook.

Making a SEA Change in the Science Community

When things haven't changed for 20 years and you don't like the *status quo*, you need to make a sea change. As Shirley Malcom of the American Association for the Advancement of Science (AAAS) pointed out at the online summer meeting of the American Association of Physics Teachers (AAPT), this has been the case for the distribution of degrees in physics by race, ethnicity, and gender. Although she acknowledged that there are insufficient numbers of African-Americans, women, and other underrepresented minorities in the physics pipeline and that it is therefore difficult to hire and retain them, Malcom also pointed up racism in the evaluation of the work of post-doctoral associates. In particular, she noted that, after George Floyd's murder, *Science*, the flagship publication of AAAS, published an editorial asking the scientific community to look at itself in the mirror for bias.

Following in the tradition of Athena Swan and the Race Equality Charter in the UK and SAGE in Australia, SEA Change was established by AAAS in 2017 to "provide scaffolding to guide and support context-specific, voluntary change within institutions that will result in systemic transformation, particularly in STEMM [Science, Technology, Engineering, Mathematics, and Medicine] . . . ." In this case SEA is an acronym for "STEMM Equity Achievement." SEA Change, Malcom continued, is based on three pillars: institute, community, and awards. Institutions joining this community are expected to undertake a self-assessment and submit a narrative and action plan based on it to obtain a bronze award, which is effective for five years, at which time it must be renewed or upgraded to silver or gold. The vision, Malcom stated, is to make diversity, equity, and inclusion the norm of the STEMM community. Eight charter institutions joined SEA Change in 2020, with five more following in 2021.

While AAAS is working with institutions joining the SEA Change community, science-specific societies are partnering with AAAS to do the same for individual academic departments. Beth Cunningham, Executive Officer of AAPT, described the Physics and Astronomy SEA Change Committee, which has members from AAPT, the American Astronomical Society, American Institute of Physics (AIP), Society of Physics Students, American Physical Society, American Vacuum Society, National Society of Black Physicists, National Society of Hispanic Physicists, and Optical Society of America. Cunningham explained that it first met in December 2017 and many times subsequently to establish the criteria and logistics of awards for departments that parallel the awards for institutions – a self-assessment, followed by a narrative and action plan, to obtain a bronze award effec-

(continued on page 14)

Going "Beyond Physics" in a physics department

According to Evan Halstead's presentation at the summer meeting of the American Association of Physics Teachers, Skidmore College has added a "bridge" experience that "interrogates power and justice in some way" for its sophomores. His presentation on "Physics and Society: a course in power, justice, and policy," described the course that he developed in his own department to meet the needs of physics majors.

This course is motivated by the underrepresentation of white women and people of color in physics and the recognition that fixing this requires finding the source of bias and its cause. Topics covered include diversity, equity, and inclusion (DEI), the academic pipeline, and science policy – regarding such things as future circular colliders (like the one once intended to be built in Texas), the 30-meter telescope to be built on land regarded as sacred to indigenous groups in Hawaii, nuclear waste disposal, and the linear *vs.* no-threshold model for radiation damage. Reading for science policy came from Roger A. Pielke, Jr.'s *The Honest Broker: Making Sense of Science in Policy and Politics*.

Students also led discussions of their own choice, and the final project was to write an editorial for a publication, write a letter to a politician or professional organization, or play the role of an expert in a controversial physics topic.

Nathan Powers and Robert Davis of Brigham Young University had a different motivation for including a unit on leadership in their lab course. Their attention was called to the statement that "NSF places high value on educating students to be *leaders and innovators* in emerging and rapidly changing STEM fields . . . ." and noted that the same message was conveyed in the *Physics 21 Report: Preparing Physics Students for 21st century Careers* and *Educating Physicists for Impactful Careers: Equipping Physics Students to Change the World Through Physics Innovation and Entrepreneurship Education* (known by its short title as *EPIC* and described in a separate story in this issue).

Wondering whether they could teach leadership authentically and involve *all* students, they found a helpful resource in Ryan W. Quinn and Robert E. Quinn, *Lift: the Fundamental State of Leadership* (2nd ed.) (Barrett-Koehler, 2015), which makes the following summative statement: "Many scholars agree that leadership does not depend on position. . . . Leadership challenges convention and inspires others to follow. The impact of such leadership is most positive and effective when cultural deviations inspire people to enhance their ethical contri-

(continued on page 14)

IBM hosts Quantum Educator Summit

by John L. Roeder

When I was a Resource Agent for the New York Energy Education Project in the 1980s I regularly took the ninth graders in my "Energy for the Future" class to the Con Ed Energy Museum. There I called attention to a device to clock workers in and out manufactured by the International Time Recording Company, adding that that company had since become known for its computers as International Business Machines, better known as IBM. In graduate school in the 1960s I had used their mainframe computers to do my doctoral dissertation. But in those days they were also known for their manufacture of electric typewriters. Having built a factory to manufacture them in Georgetown, KY, they sponsored a "Science Day" every year when I was teaching at Transylvania University in nearby Lexington. And when I came to New York to teach at The Calhoun School, I would take my students to the IBM Exhibit Center at 57th and Madison – one of the exhibits we saw in 1973 was a computer programmed to play the game "Twenty Questions." Ever at the forefront of information processing, IBM built a computer to play *Jeopardy!* and named it after founding chairman Thomas J. Watson; David Ferruci's description of it at the Science on Saturday series at the Princeton Plasma Physics Laboratory was covered in our Winter/Spring 2011 issue. Now IBM has moved on from classical computing to the newer field of quantum computing, more formally known as "quantum information science."

The U.S. government recognized the importance of quantum information science when President Donald J. Trump signed the National Quantum Initiative Act on 21 December 2018. It directed him "to implement a National Quantum Initiative Program to, among other things, establish the goals and priorities for a 10-year plan to accelerate the development of quantum information science and technology applications." To this end, the National Science and Technology Council was charged to "establish a Subcommittee on Quantum Information Science, including membership from the National Institute of Standards and Technology (NIST) and the National Aeronautics and Space Administration (NASA), to guide program activities." NIST is charged to "carry out specified quantum science activities and convene a consortium to identify the future measurement, standards, cybersecurity, and other needs to support the development of a quantum information science and technology industry." The National Science Foundation (NSF) is charged to "carry out a basic research and education program on quantum information science and engineering, and award grants for the establishment of Multidisciplinary Centers for Quantum Research and Education." And the Department of Energy is charged to "establish and operate National Quantum Information Science Research Centers to conduct basic research to accelerate scientific breakthroughs in quantum information science and technology."

A June 2020 report from the President's Council of Advisors in Science and Technology (PCAST), *Recommendations for Strengthening American Leadership in Industries of the Future*, recommended educating a quantum-enabled workforce and creating quantum programs catering to high school and undergraduate students. To showcase what it and others have done in this regard, IBM organized the first Quantum Educator Summit, held online 3-4 August 2021. In welcoming participants, Brian Ingmanson and Jay Gambetta cited IBM's educational efforts: their online Qiskit textbook; their online Quantum Composer, which allows users to set up quantum computing circuits and have them run on an IBM quantum computer; and their two-week summer courses and workshops jointly funded with NSF.

As Olivia Lanes pointed out in "Getting Started with the IBM Quantum Composer and Qiskit," quantum computers make solving problems in the following areas easier: factoring, quantum mechanics simulations, chemistry, materials science, machine learning, and optimization. IBM's three pillars of building a quantum workforce, she went on, are open access, open source, and education. This is why IBM has developed the online Qiskit textbook (accessed via ibm.com/quantum-computing). It uses Jupyter Notebooks to allow running quantum circuits with Python code to get results like those from Quantum Composer. The Qiskit textbook is also undergoing evolution into a beta version, which will consist of individual courses: Introduction (through Grover's algorithm), Traditional Algorithms and Protocols, Quantum Hardware, Quantum Machine Learning, and Labs. Presently only the Introduction is available – at qiskit.org/textbook-beta/.

Access to IBM quantum computers via Quantum Composer comes through IBM Quantum, at ibm.com/quantum-computing. Lanes pointed out that IBM has named its computer systems after cities, while its systems are named after birds (the 27-qubit Falcon in 2019, 65-qubit Hummingbird in 2020, and the 127-qubit Eagle in 2021; on tap for 2022 is the 433-qubit Osprey, and the 1121-qubit Condor slated for 2023). The results of running a quantum circuit on Quantum Composer can be seen either as a histogram or a Q-sphere.

The Qiskit Global Summer School was explained by Carmen Recio. It first operated – online – in summer 2020, when 4084 students (978 undergraduates, 761 masters-graduate students, 542 doctoral-graduate students, 216 researchers, and 167 professors) listened to 27 lectures (from 7 lecturers) and did 9 labs based on the Qiskit textbook (assisted by 51 mentors and volunteers). The first six lectures were introductory, followed by six on Shor's algorithm, three on quantum error correction, six

(continued on page 12)

Quantum Educator Summit

(continued from page 11)

on quantum hardware, and six on quantum chemistry. The summer 2021 course, which consisted of 21 lectures and 5 labs, was given to over 5000 students, with over 120 worldwide mentors, and focused on quantum machine learning.

Singh Gives Keynote Address

Keynoting the Summit was Past President of the American Association of Physics Teachers (AAPT) Chandralekha Singh of the University of Pittsburgh. She saw the current surge in quantum computing as a Second Quantum Revolution. The first, she noted, was a hundred years ago, when we began to *understand* quantum phenomena. Now, in the second, we are *controlling* quantum phenomena – for computing, communicating, simulating, and sensing.

Instead of classical computers manipulating bits, quantum computers manipulate qubits, Singh noted. In addressing what we can do to prepare students in quantum computing, she cited the results of a May 2020 workshop organized at Harvard University in May 2020 by the Office of Science and Technology Policy (OSTP) at the White House and the NSF to identify the Key Concepts for Quantum Information Science Learners: quantum information science, quantum states (superposition), qubits, measurement, entanglement, coherence, quantum computing, quantum communication, and quantum sensing. Because these concepts apply to science practices as well as to content, she added that learning quantum computing was beneficial for pursuing "quantum adjacent" careers as well.

To help *inspire*, *grow*, and *support* an inclusive and diverse quantum workforce from multiple scientific disciplines, Singh has formed a group, Q2Work, with Emily Edwards of the University of Illinois-Champaign and Diana Franklin of the University of Chicago to work as part of the National Q-12 Educational Partnership. Spearheaded by the OSTP and NSF, this partnership includes 16 members, among the more well-known being the Optical Society of America, the American Physical Society, IBM, Google, Microsoft, the Institute of Electrical and Electronics Engineers, Lockheed Martin, Boeing, and AAPT.

Singh underscored the importance of the quantum workforce being *inclusive and diverse* because of the present lack of gender, racial, and ethnic diversity in quantum fields. Only 20% of physicists are female, and only 12% of them come from underrepresented minorities. She showed a picture of physicists at a conference today that hardly looked different from a photograph of the participants in the 1927 Solvay Conference, when Mme. Curie was the token woman. The situation is similar in computer science and engineering: 20% women and 15% from underrepresented minorities in computer science, and 14% women and 19% underrepresented minorities in engineering.

Overcoming this lack of diversity requires an equitable and inclusive learning environment, Singh stressed. Teachers need to give students a sense of belonging, identity, an intelligence mindset, self-efficacy, interest, and achievement goals, which she regards as "defense tools," and develop the "offense tools" of efficient problem solving, effective problem-solving skills, transfer of learning, and robust understanding. If we don't do this, Singh emphasized, we will only further widen the gap we are trying to close.

Contributions from Outside IBM Also Presented

The Quantum Educator Summit featured the work in quantum computing education done by others as well as that done by IBM, and no less prominently. One of these efforts came out of Fermilab in Aurora, IL, where Ciarian Hughes observed that the U.S. did not make the list in a 2019 analysis of secondary school quantum physics curricula in 15 different countries because it didn't teach quantum physics widely enough. Mindful of the aforementioned June 2020 PCAST report, he enlisted Joshua Isaacson, Anastasia Perry, Ranbel F. Sun, and Jessica Turner to produce an open-access textbook, *Quantum Computing for the Quantum Curious*, for high school students. Perry, who teaches at the Illinois Math and Science Academy, and Sun, then teaching at Phillips Academy, also used it in their classes prior to publication and spoke at the Summit about their experience. (Perry used it in a one-week intersession in January 2020, in person, and in January 2021, online. Sun used it in a 2-week end-of-year unit on modern physics.) After this quintet worked for three years on this project, their text was published in March 2021 by Springer. Thanks to funding from IBM, it can be downloaded from the Springer website without charge.

Quantum Computing for the Quantum Curious consists of nine chapters, organized into three streams. The first two chapters, "Introduction to Superposition" and "What is a Qubit?" apply to all three. One stream after that consists of chapters 4 and 5, on "Creating Superposition: Stern-Gerlach" and "Quantum Cryptography" (using the BB84 protocol). Another consists of chapters 6 through 8, on "Quantum Gates," "Entanglement," and "Quantum Teleportation." The third stream consists of chapter 3, "Creating Superposition: Beam Splitter," and chapter 9, "Quantum Algorithms." A tenth chapter contains worksheets, activities, and labs. The level of items in the book is indicated by a circle for "fundamental," a square for "intermediate," and a diamond for "advanced."

(continued on page 13)

Quantum Educator Summit

(continued from page 12)

Still another salient effort in quantum computing education has come from Qubit x Qubit, a nonprofit institute focused on training a future diverse quantum workforce. Ingmanson introduced Kiera Peltz, Executive Director of Qubit x Qubit, personally at the beginning of the second day of the summit, after we had already learned from Amir Karamiou's presentation on "Teaching 8000 Students During the Pandemic" how he had taught the Qubit x Qubit course to high school students and above during the 2020-2021 academic year. Karamiou began by observing that the goal of the course is "to create an equitable quantum workforce by equipping the next generation with the quantum computing skills necessary for work." It consisted of a weekly two-hour lecture (synchronous or asynchronous), one-hour lab/recitation (synchronous, with about 200 students per group), and homework, amounting to a five-hour total weekly commitment, for 24 weeks.

Matrices and vectors for gates and qubits had to be introduced, he said, also Dirac notation for quantum states, as these topics are normally not taught to high school students. The IBM Quantum Composer and Qiskit text were used. Topics covered in the first semester included classical computing, quantum computing in abstract, vectors and complex numbers, matrices, probability, introduction to Python, math for quantum mechanics, and Dirac notation. The second semester covered an introduction to quantum mechanics (wave-particle duality, superposition, entanglement, the Stern-Gerlach experiment, and Schrödinger equation), qubit and Bloch sphere, quantum circuits, Qiskit, quantum key distribution, superdense coding and teleportation, Deutsch-Josza algorithm, experimental metrics and implementations, Grover's algorithm, Variational Quantum Eigensolver, and QAOA.

Karamiou reported that 88% of the students beginning the course finished it, compared with a 3-6% completion rate for Massive Open Online Courses. About 800 of the students were limited in doing labs because their only online access was through cell phones. Ninety-nine percent responded that they are more likely to take a STEM course in college, and 96% felt more confident in STEM skills, with the gender gap in confidence declining from 14% to 7%. Peltz added that these students came from 125 countries and that 55% were from traditionally underrepresented backgrounds.

Karamiou stated that the 2021-2022 academic year Qubit x Qubit course is slated to begin 19 September 2021 and end 10 April 2022, and that registration can be done at <www.qubitbyqubit.org/programs>. Peltz added that it will be conducted synchronously, with pass/fail grading. She stated that over 100 school districts gave high school credit for the course last year and that they are looking to join more local school districts in partnership in the coming year. Basic trigonometry, she said, is the only prerequisite.

One additional effort in quantum computing education was "AAPT Quantum Computing Preparation," presented by Mark Hannum of AAPT. He began with three salient reasons to teach quantum computing *now*: 1) "Quantum computers have overcome the initial technical barriers and now their promise seems achievable"; 2) "The physics and mathematics of two-state systems can be integrated into current high school courses" (and is easier to learn than the psi-function of the Schrödinger equation); 3) "We need to start to prepare all of our students to take advantage of the future job market." With funding from both NSF and IBM, AAPT brought 24 physics, mathematics, and computer science teachers together online for 2 hours for 15 Saturdays in the fall of 2020 to learn two-state quantum systems and the application of quantum computing through Shor's algorithm, using Qiskit, then did the same for 20 teachers in person for five days in summer 2021 in Washington, DC. Further making the case for teaching quantum computing to high school students, Hannum stressed that the only mathematics prerequisites are two-dimensional vectors, 2 x 2 matrices, complex numbers, and some probability. He emphasized that the Stern-Gerlach experiment provides an easy-to-understand two-state system and added that the Bloch sphere offers a math-free understanding.

A further effort in quantum education, also coming from AAPT, was cited by Singh in her keynote address but was not presented at the Summit. This is the Quantum for All initiative, focused on quantum concepts, from the Physics Teaching Resource Agents (PTRAs), led by Karen Jo Matsler.

Quantum "Desserts"

In addition to the "main course" at the Summit, there was also "dessert," consisting of auxiliary features that can make quantum computing more understandable and appealing. Chris Cesare of the Joint Quantum Institute at the University of Maryland described "The Quantum Atlas: a multimedia guide to an unseen world," which he co-created. It amounts to a glossary of terms and concepts used in quantum computing, using many interactive elements. It can be accessed at <quantumatlas.umd.edu>.

James Weaver of IBM also presented his "Quantum Music Playground," which he described as a "playground for composing music using quantum states, implemented as a Max [plug-in] for Live device in Ableton Live11, and includes a MicroQiskit quantum simulator." The idea, he said is to "ascertain ways to hear a quantum state, and create a device . . . to compose music using state vectors," as represented by histogram outputs from

(continued on page 14)

Back to the Moon!

We're going back to the Moon! That was the message, loud and clear, from the four NASA engineers who spoke at the summer meeting of the American Association of Physics teachers at a session scheduled for 31 July 2021, titled "Back to the Moon and off to Mars." According to Rob Stough, Clark Essty, Chris Culbert, and Nehemiah Williams, the program charting our return to the Moon is named Artemis, the twin of Apollo (name of our previous lunar exploration program) and goddess of the Moon. Artemis I, which is uncrewed, is scheduled to launch on 21 November this year. Artemis II will carry a crew but will achieve only a lunar orbit. Lunar landings are planned for Artemis III and IV.

In comparison with what project Apollo brought to the Moon, Artemis will appear to be doing some rather heavy lifting, using a Human Landing System which will transport astronauts between lunar orbit and the lunar surface and be their habitat while they are there. While they are there, they will also be provided with the following elements of a lunar space camp: a portable nuclear reactor to provide electrical energy, a Foundation Surface Habitat, meant to last 15 years and support a crew of two to four for 30 to 60 days, a pressurized rover, also meant to last 15 years and be able to provide 30-day habitation for two, and an unpressurized rover, designed for a lifetime of 10 years. These specifications suggest that Artemis astronauts will spend extended time on the Moon (compared with the Apollo missions), much will be spent on work preparing for subsequent missions to Mars.

Williams showed a video tracing the path of a 2039 flight from Earth to Mars, chasing Mars around the Sun, with a round trip time of 850 days, including a 50 stay there. He explained that flights could be initiated when Mars is either in conjunction or opposition, the latter requiring more energy and the former requiring more time and exposing astronauts to more radiation. He also explained that a mission to Mars requires launching bigger

(continued on page 17)

Quantum Educator Summit

(continued from page 13)

running quantum circuits on the Quantum Composer. He demonstrated a system programmed to play "Twinkle, Twinkle, Little Star." Slides for Weaver's presentation of the Quantum Music Playground can be accessed at <https://slides.com/javafxpert/quantum-music-playground>.

Weaver also presented "Qiskit Blocks – a Minecraft-like game to learn quantum computing," which challenges users to insert the proper quantum gate to produce a desired quantum qubit state and thereby open the door to the next room. Only H, X, and Z gates are used in the "rooms," through which Weaver toured us, but other gates, he said, are available in the "quantum garden." For links to a video and instructions to set up his game, access his slides at <qisk.it/blocks>.

Last year I wrote about the two-week workshop Steve Schnetzer of Rutgers University offered to the New Jersey section of AAPT. He repeated that workshop this summer, and also offered a one-week advanced follow-up, which I signed up for. Schnetzer subsequently called our attention to the Quantum Educator Summit, and I'm grateful for both opportunities. But if it hadn't been for what I learned in his workshops, I'd've been lost at the Summit. Meanwhile, the Summit has given me reason to try to put together an introductory course for the intersession at The Calhoun School next April.

"Beyond Physics"

(continued from page 10)

butions and the welfare of the people who hold a stake in the situation." Understanding leadership as a set of skills, attitudes, and behaviors required all students to be involved. The four fundamental areas considered were purpose *vs.* comfort centering, internally-driven *vs.* externally-directed, others *vs.* self-focused, and externally open *vs.* internally closed.

They included reading and group/class discussion in the course, and students were asked to write final reflections. Because students objected to the disconnect between leadership and other course goals when the leadership component of the course was infused into it, leadership is now presented as a separate unit in the course. Powers and Davis find it important for faculty to be vulnerable and relating leadership to student improvement.

SEA Change

(continued from page 10)

tive for five years, at which time it must be renewed or upgraded to silver or gold.

Cunningham stated that this work was funded by an AIP Venture Partnership Grant in 2019 and that Alexis Knaub was hired to manage it in 2020. The draft partnership charter constructed in fall of 2019 was finalized in 2020 and describes membership eligibility, decision-making structure, financial procedures, and meeting rules and guidelines. This charter needed to insure equity among the societies, based on a consensus of no opposition from any of them for anything to proceed. Next came development of the documents to evaluate the departmental narratives and action plans, which AAAS will use to evaluate narratives and action plans from departments in other sciences. Five departments have signed up for the pilot cohort, and two more have indicated interest in being in the second cohort. Cunningham also acknowledged unresolved challenges of sustainability and scalability.

Opportunities in Advanced Manufacturing Highlighted

The United States Department of Education hosted a webinar on 28 July 2021 to explain the U.S. government's plans and programs for training the workforce for jobs of the future in Advanced Manufacturing (AM). Host Patti Curtis explained that the basis for the webinar was the report, *Strategy for American Leadership in Advanced Manufacturing*, issued by the Subcommittee on Advanced Manufacturing of the National Science and Technology Council in 2018. The report focused on three elements, she said – technology, workforce, and supply chain – and the webinar would focus on preparing the workforce, in terms of four goals: 1) attract and grow tomorrow's manufacturing workforce, 2) update and expand career and technical education (CTE) pathways, 3) promote apprenticeship and access to industry-recognized credentials, and 4) match skilled workers with industries that need them.

In her welcoming remarks, Acting Assistant Secretary of Education for Career, Technical, and Adult Education Amy Loyd wished all participants a happy "Made in America" day, in accordance with President Biden's proclamation to call attention to his intention to revitalize American manufacturing by increasing jobs in the manufacturing sector. Loyd pointed out that the holders of these jobs typically earned wages about 10% higher, plus benefits, and that CTE, which she noted was "inextricably interdependent" with STEM education, was an optimal pathway to prepare for them. Students with a concentration of CTE courses in high school, she added, have shown higher high school graduation rates than similar students not taking these courses. Furthermore, students with a concentration of CTE courses in high school have shown a greater tendency to continue their education at the post-secondary level, Loyd continued, noting that education is lifelong, not "one and done."

Next to speak was Michael Britt-Crane of the Department of Defense. He began by acknowledging that employment in American manufacturing had declined – from 17.5 million in 1987 to 12.5 million in 2017. Yet he projected that there will be 2.4 million unfilled manufacturing jobs by 2028. But they will not be the kind of manufacturing jobs that characterized what he considered to be the first three stages of the Industrial Revolution, based on mechanization, mass production, and automation. They will be characterized by what he considered to be the fourth stage of the Industrial Revolution: cyber-physical systems. The skill needs for this fourth stage, however, are not the present skills of the workforce pool, Britt-Crane lamented. The present labor supply is not meeting employer demand. One reason for this is that present educational curricula lag rapid technology advances and that there has been insufficient connectivity with industry.

To remedy this disconnect, the Department of Defense has adopted a key strategy to 1) modernize manufacturing education by a) developing talent and technology concurrently, b) employing a disruptive innovation in learning tools, and c) modernizing CTE to expand non-traditional learning models; 2) expand the talent acquisition pool; and 3) drive action regionally. To do this, the Department has been developing the Manufacturing Innovation Institute Network of public-private partnerships since 2012.

Cindy Waters presented another Department of Defense program designed to produce the manufacturing workforce that Britt-Crane described: the Manufacturing Engineering Education Program (MEEP), of which she is the Lead Coordinator, started in 2017. Its mission is to "attract, inspire, and develop exceptional STEM talent across the education continuum to enrich our current and future DoD workforce to meet defense technological challenges" in order to achieve its vision of "a STEM talent pool with minds for innovation, diversity of thought, and technical agility to sustain the Department's competitive edge." In the first three years of its existence MEEP has presented awards to 13 distinguished educational and industry partners totaling up to $50 million.

Emily McGrath, Director of Workforce Development, Education, and Training for NEXT FLEX, pointed out that her company is both an MEEP grantee and a member institute of the Manufacturing Innovation Institute Network that Britt-Crane had described. NEXT FLEX can play this dual role because they are engaged in the emerging technology of flexible hybrid electronics (FHE) as well as in workforce development. McGrath pointed out that developing a workforce for a new technology such as FHE is different from developing a workforce for a technology that has already been commercialized, because the requirements of the workforce will evolve with the technology. She described several programs designed to develop the workforce needed at various stages of product development, including their FLEX FACTOR "project-based learning program designed to inform, inspire, attract, and recruit the next generation workforce" for students in schools. In this program, "small teams of students are challenged to 1) Identify a real-world problem, 2) Conceptualize a hardware device to address the issue, 3) Build a business model around the product, and 4) Pitch the project to a panel of representatives including members of industry, academia, and government."

Alexis Vogt, Professor of Optical Systems Technology, Monroe Community College (MCC) of the State University of New York, showed a panorama of optical devices, some used in everyday life, others used in military defense – and pointed out that they had one thing in common: they all needed optics technicians for their manufacture. An optics technician "works with scientists and engineers in research, development, design, manufactur-

(continued on page 17)

Just an Egg…But What an Egg!!

by Bernice Hauser, Primary Education Correspondent

While on Cape Cod this past summer, my grandchildren, Skyler and Adam, asked me if I had any memorable early childhood science lessons. "Oh yes," I replied, and immediately shared with them my *first* lesson as the newly-appointed primary science coordinator nearly 30 years ago at the independent Walden School located in New York City.

I told Skyler and Adam that I chose an egg because I am a firm believer in developmentally appropriate practices in serving young children — that is, starting from experiences that young children already have familiarity with. I discovered that these four and five year-old students often had hard-boiled eggs served to them in the school's lunchroom — so using an egg as our exploration appealed to me both professionally and also personally as I would be able to supply each child with his/her own egg as we do our investigations.

"Can anyone identify the object that I am holding in my hand?" I asked as I seated myself down at a table alongside several five-year-olds. Practically in unison they shouted out, "It's an egg."

I replied, "How do you know it's an egg? How do you know it is not a toy shaped like an egg? Or a statue molded in the shape of an egg?" Silence. But then I recalled a young child saying that she had helped her mother crack eggs to bake cakes. . . . "Perhaps we should crack this egg to see if it is real?" I continued All the students thought this was a good idea.

I located a big bowl on a shelf, placed it in the center of the table, had the children stand up as the student cracked the egg into the bowl. We then discussed what was in the bowl while I also tried hard to ensure that they were using their five senses. Back then we recorded responses on big white pads, not yet having at hand all the technology available today, and these were some of them: "I don't smell anything at all." "It looks like a moon." "It is a yellow ball." "I see a sun." "Maybe it's a fish swimming in water."

The exploration part of the lesson was coming to its end. I knew I could introduce new vocabulary to the children if they drew what they could see. So without hesitation, I proceeded to give each child a small plastic bowl and his or her own uncooked egg. They were instructed to crack the shell of the egg and let its contents flow and remain in their plastic bowl. They followed this process gleefully. Then I handed out drawing paper and crayons and magic markers and suggested that they draw what they saw in their respective bowls. Some of them were disappointed that their yolk had dissipated into a glob of yellow liquid. (This was an opportunity for future lessons.)

While they drew their impressions, I drew on the white pad a picture of a huge yolk encased in a white shell (calcium carbonate), the liquid surrounding the yolk (albumen) and the air sac that is the space between the shell and the albumen. While I did not expect them to remember this new vocabulary, I reasoned that perhaps the word *yolk* would resonate with them as they increased their science proficiency.

What I tried to impress upon Skyler and Adam is the fact that we build on these students' interest and knowledge with many follow-up experiences. These included a discussion of where eggs come from; and when one student suggested that eggs come from the supermarket, I quickly affirmed his response by saying yes, we can *buy* eggs from supermarkets but used that response to create many additional lessons.

It was most essential to inform the parents of these young students about the activities that we were doing with their children. They are our partners in their child's education. We always encouraged questions, comments, and their creative input, plus their assistance when feasible to continue discussion on the topic being studied.

Additional experiences include showing videos of hens laying eggs, farms, and farm animals; or a visit to Kerbers Farm on Long Island (309 West Pulaski Road (Oakwood Road) Huntington, NY, 631-423-4400, kerbersfarm.com) or to the hall of ornithology of the American Museum of Natural History. If you want simple egg recipes to use with young students, I highly recommend Craig Claiborne, *Kitchen Primer* (Knopf, New York, 1969) for a plethora of easy to follow egg recipes suitable for both aspiring child chefs and seasoned adult chefs. The 1990 *New York Times Cook Book* contains egg recipes on pages 96-130. One favorite egg dish is to place sunnyside cooked eggs on top of pancakes and drizzle with your favorite topping.

In the 16 August 2021 issue of *New York Times*, page 2, food writer J. Kenji Lopez-Alt wrote the following:

". . .What I do for the *Times* is a little bit different. I really try to focus on research beyond just the experiments at home. I do a lot of reporting and interviewing and talking to chefs about their recipes. . . . there's the general term *science* which is really just the scientific method: hypothesizing, designing experiments and tracking results. For example, I think my first column at the *Times* was about *what factors* affect how easily a hard-boiled egg is going to peel. I designed my own experiments. I cooked eggs multiple different ways, and then I had like a hundred people come in and just peel eggs and collect the data. I saw when I cooked the eggs one particular way 80 percent of the people were able to peel the eggs with only one of the eggs getting a few little cracks in it. Whereas,

(continued on page 17)

Just an Egg

(continued from page 16)

if I cooked it a different way, only 40 percent of the people were able to do that. We found that *steaming* the eggs was the best way."

A follow-up exploration on "What Can We Do with Eggs?" is as follows: Place in the palm of your hand one uncooked egg (hold it over a bowl in case it cracks). Squeeze the egg as hard as you can. It should not break. Explanation: Like the force from the palm of your hand, a hen's weight spreads out evenly over the rounded shape of the egg shell when she sits on the egg. Therefore the egg does not break.

Another is to place newspaper on empty floor space. Place an uncooked egg on the newspaper and give it a gentle push. Watch closely to see how it rolls. Does it roll fast and straight? If not, how would you describe its movement? Repeat the experiment with a hard-boiled egg.

Yet another comes from using available materials in the classroom to fashion an inclined plane. Have a student roll a ball similar to the size of an uncooked egg down this plane. Observe its movement. Then repeat this exploration substituting the uncooked egg for the ball. Observe the outcome. Compare the outcomes of these explorations. Discuss possible explanations for the different results.

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Back to the Moon!

(continued from page 14)

payloads and a heat shield for landing; and coming back requires more than 20 tons of ascent propellant and advanced heat shields. Being on Mars would subject astronauts to dust storms, a lengthy stay with limited resupply, and a round trip communication period of 44 minutes. Supportive hardware would have to be sent to Mars's surface before humans land there.

Advanced Manufacturing

(continued from page 15)

ing & quality control, manufactures optics, and performs testing and evaluation of optical components and systems."

There is a worldwide shortage of optics technicians, Vogt continued. A fifth of the present technicians and engineers are approaching retirement, and more than 550 job openings go unfilled annually in western New York State alone. Three quarters of medium-sized German companies claim that the shortage impairs their ability to innovate. Amidst this worldwide shortage Vogt then showed a slide that said that "Monroe Community College is the world's only college awarding associate degrees in precision optics," and that was on its last leg with only five students when she arrived at MCC five years ago. She then went on to describe MCC's programs: 1) a one-year certificate, 2) a two-year Associate of Applied Science (AAS) degree, and 3) a 2 + 2 transfer program with the University of Rochester's Institute of Optics, the Rochester Institute of Technology's Center for Imaging Science, or the University of Arizona's College of Optical Sciences. What initially brought strength to MCC's optics programs was the Defense Engineering Education Program in Optics (DEEP OPS), which assisted the Department of Defense in finding the optics technicians they needed, and funding from the Department of Defense, NSF, and various corporations.

Because the optics industry is well represented in Rochester, NY, where MCC is located, all the faculty in MCC's programs can be drawn from the optics industry. Moreover, they can provide apprenticeships for their students in the optics industry as part of their training. Because the pandemic incentivized MCC to provide all their programs online, they are in the process of making them available to students unable to come to Rochester; and they have also reached down to high school students by training high school teachers to teach the MCC optics course to their students for MCC credit, also with the possibility for apprenticeships.

In the following Q&A both Waters and Vogt agreed that musicians, gamers, and others with strong hand-eye coordination are excellent candidates to become optics technicians and that educating students about optics should begin in elementary school. Britt-Crane added that learning to be an optics technician at MCC is an opportunity for good pay without student debt. And McGrath emphasized the importance of learning how to learn, since knowledge continually evolves.

Call to Action

(continued from page 1)

vides the basis for the entire modern technical sector . . . and the process for revising knowledge based on new evidence that underlies the STEM disciplines." (p. 19)

The next section of the report is "A Vision for **Better, More Equitable Science Education**." The Committee authoring the report writes that "Our vision is that every student experiences the joy, beauty and power of science, learns how science can be used to solve local and global problems, see the pathways they can take into science-related careers, and feels welcomed and valued in science classrooms." (p. 20) In order for students to have this experience, they must *do* science, not just read about it. To this end, this report endorses the *Framework for K-12 Science Education*, on which the Next Generation Science Standards (NGSS) are based. Teachers need to know that their job is to provide students opportunities to build their own knowledge rather than impart it to them. Students of color, lacking role models, need to be especially engaged and welcomed.

In this vision, "higher education makes it a priority to broaden opportunity for populations of students underrepresented in STEM professions and produces science and engineering graduates of all races and ethnicities in at least proportion to their percentage share of the American population." (p. 25) Then "all students finishing postsecondary programs or degrees leave understanding even more deeply than they did upon high school graduation how science and scientific thinking are relevant to their careers and lives." (p. 25) "If the nation fulfills this vision and extends the opportunity for a high-quality science education to all, . . . America will thrive as a nation of science 'haves'" (p. 25), in contrast to an "American citizenry of science 'haves' and science 'have nots,'" (p. 21) which would result from a science teaching cadre using "antiquated instructional practices" (p. 21) and not providing role models for students of color.

The next section of the report asks "How Far Are We from This Vision for All Students?" The short answer to this question is "very," as a result of lack of emphasis of science in the curriculum and the inequities in teaching it. "Students of color and students experiencing poverty are particularly unlikely to have high quality science learning experiences across K-16," this section states in its first paragraph (p. 27). It continues by noting that elementary schools spend an average of only 20 minutes per day on science, contrasted with 90 minutes on English/Language Arts and 60 minutes on math, largely due to the need to prepare students for standardized tests. This leaves elementary students less prepared to learn science in middle school. Moreover, the time spent on science teaching is not always spent using the teaching methods called for in the vision of the preceding section. Moreover, schools in high-poverty areas are particularly limited in their science education by inadequate materials and facilities.

This section of the report continues by observing that "an underprepared, nondiverse teaching workforce is also a challenge." (p. 29) "In schools that serve higher percentages of students of color and students living in poverty . . . students are more likely to be taught by inexperienced teachers and, in secondary schools, are less likely to be taught by a teacher with a relevant degree or advanced courses in the subject taught." (p. 28) "Staffing shortages are [also] more acute in schools that serve higher percentages of students living in poverty and in rural areas." (p. 28) Moreover, "the science teaching corps is also not diverse. Eight of 10 . . . science teachers are White" and "There are particular difficulties with attracting and retaining teachers of color," who "are more likely to work in schools that are in high-poverty, urban communities and . . . are more likely to change schools or leave the profession than White teachers." (p. 30) "Science students in high-poverty secondary schools, rural schools, and schools with high numbers of students of color are less likely to be enrolled in science prep courses." (p. 30) "Quality of science instruction is also a problem in post-secondary education" and "students of color were more likely to blame themselves for learning problems instead of the poor teaching." (p. 32)

Continuing to discuss post-secondary education, this section continues by stating that "the majority of all students who enter 4-year institutions intending to major in the natural science, technology, engineering, and mathematics do not earn a degree in these fields," often because of poor teaching. "Comparable percentages of Black, Latino/a, and White college freshmen . . . declare a STEM major," but "only 43 percent of Latino/a students and 34 percent of Black students persist to earn a STEM degree compared to 58 percent of White students." (p. 33) In addition to educational inequities, "housing and employment discrimination and discriminatory lending practices" (p. 34) have also contributed to "the nation's poor track record of preparing a STEM workforce that looks like the nation." (p. 34) This propagates the inequity in income ($70,642 average for Whites, versus $51,540 for Latino/a, $41,361 for Blacks) and net worth ($171,000 for White families versus $17,150 for Black).

Having acknowledged that we're not close to the vision the report has put forth for **Better, More Equitable Science Education**, the next section of the report asks a further question, "How Do We Get There?" Here the Committee puts forth five "priorities for advancing **better, more equitable science education**," (p. 37) as follows:

1. "Communities will need to provide the time, materials and resources to support high-quality science

(continued on page 19)

Call to Action

(continued from page 18)

learning experiences for all students across the K-16 continuum." (p. 37) This means insuring enough sufficiently-prepared teachers to teach all students.

2. "Having a high-quality diverse workforce for teaching science across K-16 is essential." (p. 38) This means switching from teaching based on lectures and textbooks to "engaging student-centered ways that reflect current evidence about how people learn." (p. 38) Here the report also reiterates the earlier argument that "Science is an essential literacy on par with English/Language Arts and mathematics" (p. 38) and also reiterates that "Attracting and retaining more science teachers of color is top priority for all levels of education." (p. 39)

3. "Students need clear, supportive pathways across grades 6-16." (p. 40) These pathways are critical to help students transitioning into preparation for STEM careers, especially in the 11-14 grade interval. Because many community college students are Black and Latino/a, these institutions are especially important as mentors.

4. "Science assessments and accountability systems need to be aligned with the vision for high-quality science instruction." (p. 43)

5. "Use evidence to document progress and inform ongoing improvement efforts." (p. 43) "These efforts will require substantial financial investments and will take time." (p. 45)

Next come the "Recommendations" – eight of them. Because most of them are like recommendations in the many previous reports on science education, attention will be given here only to how these recommendations are different. Recommendations 2 and 3 argue that Congress and State Education departments "should include science [along with English/Language Arts and mathematics] as an indicator of academic achievement," (p. 46) but they also argue that the assessment not be limited to a single test. Recommendation 4 addresses the inequity in science education in stating that "National stakeholders . . . should undertake coordinated advocacy . . . to addressing disparities in opportunity." (p. 47) And recommendation 8 calls for the federal government to "develop an annual 'STEM Opportunity in the States' report card that documents the status of K-16 science, technology, engineering, and mathematics (STEM) education across each of the states and territories and tracks equity of opportunity for students in science specifically and in each of the other STEM disciplines." (p. 49)

"In Conclusion," the Committee calls for "a unified voice that science education is a national priority because it is essential to our nation's vitality, the maintenance of its democracy, the quality of life its people lead, the health of its economy and its ability to respond to big challenges." (p. 51) It also notes that "the nation has a the opportunity to reset science education so that it is **better** for all Americans and **more equitable** for populations of students from rural communities and those who are of color or experiencing poverty." (p. 51)

Call to Action can be accessed from <nap.edu/resource/other/dbasse/cta-science-education>.

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Johanna Miller, "The Amazon is reaching its carbon tipping point," *Phys. Today*, **74**(9), 12-14 (Sep 21).

Analysis of atmospheric samples gathered by air at four locations in the Brazilian Amazon for carbon dioxide and carbon monoxide allows not only measurement of change in carbon dioxide concentration but also inference of the change due to fires, and, from this, determination of the ecosystem flux of carbon dioxide. At the southeasternmost of these four locations the ecosystem flux is found to be positive, showing that this portion of the Brazilian Amazon has become a carbon dioxide source rather than a sink.

2. David Kramer, "Better ways to store energy are needed to attain Biden's carbon-free grid," *Phys. Today*, **74**(9), 20-22 (Sep 21).

An electricity grid free of carbon dioxide emissions and based heavily on renewable energy sources will require considerable backup to store energy generated by Sun and wind when it is not immediately needed. Since the lithium-lithium ion batteries used in electric vehicles have storage times limited to eight hours and use a flammable solvent electrolyte, "redox flow batteries," which "consist of tanks of aqueous chemical redox pairs," are preferred. Also considered are "nonchemical storage options," including "hydrogen, gravity-and thermal-based systems, and compressed air."

3. Kottie Christie-Blick, "Climate Justice: Science for a Better World," *Sci. Teach.*, **89**(1), 20-26 (Sep/Oct 21).

"If you teach just the facts about our increasingly unstable climate, but fail to address questions such as who wins and who loses from this change, you are missing out on the opportunity to influence history," Christie-Blick writes. "Climate change is primarily caused by emissions from richer countries, and the wealthiest within those

(continued on page 26)

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Paul Sen, *Einstein's Fridge* (Scribners, New York, 2021). 305 pp. $28.00. ISBN 978-1-5011-8130-6 ebook 978-1-5011-8132-0.

"(Thermodynamics) is the only physical theory of universal content, which I am convinced . . . will never be overthrown," Einstein is quoted as saying in the prolog to this book. But information about the refrigeration system he and Leo Szilard patented represents just a small portion of its contents, because the author is convinced that the history of science is what matters. He not only provides valuable insights into the evolution of thermodynamics but includes fascinating information about the scientists involved and the times in which they worked.

Sen opens his book with information about economist and businessman Jean-Baptist Say, who visited Britain on behalf of France to investigate the reason for the surging English economy. Say had visited Britain in the 1780s, and when he again visited in the 1810s he found the increase in the number of steam engines in use astonishing. Steam engines had a dramatically stimulating effect on the British mining industry.

Sen describes the love-hate relationship the English had with science in the late 1700s. While they enthusiastically attended public lectures on natural philosophy, the English higher education system offered no courses promoting the study of physics or engineering. At the same time, the French revolutionary government promoted the study of science and mathematics, "as weapons in a war against superstition and arbitrary aristocratic privilege."

The second chapter of the book extensively covers the life and work of French natural philosopher Sadi Carnot. While attending the Conservatory of Arts and Crafts, Carnot encountered chemistry professor Nicholas Clement. Clement had quantified heat by developing the concept of the calorie, identifying it as the amount of heat needed to raise the temperature of one kilogram of water one degree centigrade (today's definition of a "food calorie").

In 1824 Carnot published a book written for nonscientists. He employed Clement's calorie and described the relationship between heat and cold in a heat engine. Sen describes this description as marking the first step in the history of thermodynamics.

He then goes on to describe the life and work of James Joule. Interestingly, at the age of sixteen, Joule was enrolled for private lessons with John Dalton, known for his theory of atoms at the onset of the nineteenth century. Working with a dynamo, Joule discovered that the electric current produced by the dynamo could be used to affect the temperature change of water that was heated by the current from the dynamo. From his investigations he concluded that the current produced by a dynamo could "increase or destroy" the heat held by the water. Through further investigation he discovered what he called "the Mechanical Equivalent of Heat." Using English units, Joule defined a unit of heat as the amount of heat needed to raise the temperature of a pound of water by 1 °F.

Sen describes Joule's first encounter with William Thompson (later Lord Kelvin) during the summer of 1847, who identified Joule's work as "A most important measurement to bring forward." After describing the work done by Lord Kelvin, Sen presents information about physician Herman Helmholtz, who investigated the nature of heat and how it is a work agent, and Rudolf Clausius, who Sen characterizes as the father of theoretical physics as he "eschewed experiments and instead sought truth with the aid of logic and mathematics." He describes the reasoning Clausius used in a paper published in *The Annals of Physics* in 1850, in which he established what are now known as the first two laws of thermodynamics; the law of conservation of energy and the principle that heat never spontaneously flows from cold to hot. Sen indicates that the statement of these principles marked the official birth of a field of science.

The seventh chapter in *Einstein's Fridge* is titled "Entropy," and Sen begins by describing Lord Kelvin's development of the absolute temperature scale in the 1850s. (In 1954, the General Conference of Weights and Measures established the units of the scale as "Kelvins.") He then goes on to describe Clausius' development of the concept of entropy and states that the equation $\Delta S \geq 0$ is "one of the most important in all science." Concluding the chapter on entropy with information about the investigation of the age of the earth, Sen writes, "Heat was driving the world into the future, and scientists knew how heat behaved," but the nature of heat was still unresolved.

The chapter titled "Collisions" includes interesting information about James Clerk Maxwell and his work. There is a description of Maxwell swimming, and working out on a gymnastics pole. Maxwell enjoyed teaching, and Sen writes of him working with his students to devise investigations of heat. One of those investigations involved estimating the amount of heat needed to melt or boil different substances. Maxwell's wife Katherine is described as having an interest in the experimental side of physics, and assisting her husband with investigations done in a laboratory they constructed at their house, and

(continued on page 21)

REVIEWS

(continued from page 20)

Sen provides information about an investigation of the kinetic theory of heat that she and James worked on which resulted in the verification of a prediction of the theory. Later in the book, Sen also describes how Maxwell came to develop his theory involving energy, entropy, and information, which he published in a book titled *Theory of Heat.* (That book led to work done by Leo Szilard involving information processing.)

After his chapter on "Collisions" Sen details the lives and work of Ludwig Boltzmann and Josiah Willard Gibbs in developing the kinetic theory, as well as a statistical analysis of the second law of thermodynamics. Information about Gibbs includes a very interesting description of his father's role in legally freeing the slaves who were being transported on the *Amistad.* Sen describes how Gibbs was the first to use *thermodynamic maps* to describe changes in the physical properties of a substance when it underwent changes in pressure, temperature, or volume. Historical information about refrigeration is included, and Sen writes, "Think of a refrigerator as a device in which time slows down." He provides details about the development of the concept of reaction spontaneity, activation energy, and Gibbs free energy (leftover energy from a chemical rection). Sen indicates that all life on Earth is enabled by the concept of Gibbs free energy.

Sen titles the chapter describing the work of Max Planck "Quanta," and the chapter that describes the life and work of Emmy Noether "Symmetry." Both chapters are interesting and informative to read. Contributions from additional scientists, physicists, and mathematicians include the work of Albert Einstein, Leo Szilard, Claude Shannon, Alan Turing, Stephen Hawking, Jacob Bekenstein, John Wheeler, John Tyndall, and others. I was surprised to learn that Alan Turing was an accomplished distance runner, having completed a marathon (40 km) in an impressive two-hours and forty-six minutes.

Sen's book was enjoyable to read and is replete with good information.

\- Frank Lock

(*Editor's Note*: Frank Lock is a retired high school physics teacher and Climate Reality Project Leader/Mentor.)

Timothy C. Winegard, *The Mosquito: A Human History of Our Deadliest Predator* (Dutton, New York, 2019). x + 486 pp. $28.00. ISBN 978-8-524-7434-3.

"We are at war with the mosquito" — 110 trillion of them, females purveying "at least fifteen lethal and debilitating biological weapons" against us with their bites, accounting for more human deaths than any other species on Earth (830,000 due to mosquitoes *vs.* 580,000 due to humans in 2018). And we spend $11 million per year fighting this war.

This is how Winegard begins his book. Although he is a history professor and his subtitle indicates that the bulk of what he provides his readers is historical, he begins with a first chapter of scientific facts about mosquitoes needed to appreciate their effect on history. Female mosquitoes (who do all the biting) can locate humans by their exhalation of carbon dioxide and are attracted by lactic acid in sweat and by applied fragrances. People with type O blood and pregnant women (who respire more carbon dioxide) are twice as likely to be bitten. After finding a prime blood vessel (within ten seconds to reconnoiter) a female mosquito "inserts two serrated mandible cutting blades" (like those in an electric knife) to form a slit through which the proboscis can suck blood. After three to five milligrams of blood are sucked, saliva containing anticoagulant and toxin are injected into the human. The mosquito excretes the water from the blood and retains the rest to nourish her eggs. The eggs are fertilized when females fly into a swarm of males to find a mate, and the time from laying her eggs in water to adult maturation takes one week. Mosquitoes live an average of one to three weeks and rarely travel more than 400 meters. This has been happening up to 190 million years.

Disease-causing organisms such as bacteria, viruses, and parasites had evolved before mosquitoes, but by becoming vectors to help these organisms infect humans, mosquitoes helped these organisms reproduce more easily. Before humans arrived, mosquitoes preyed on dinosaurs; and beaked birds, thought to have descended from dinosaurs, "are still a primary reservoir for numerous mosquito induced viruses" (p. 17), which numbered six in 1930 and now number 505. Fossil evidence suggests that a form of malaria parasite appeared in birds 130 million years ago and has plagued human ancestors for six to eight million years. Transmitting it and more than 14 other diseases are the Aedes and Anopheles mosquito, which have survived by their adaptability, yet perform no role in an ecological relationship with other species, except perhaps to kill humans.

There are three groups of mosquito-borne pathogens: 1) viruses, spread mostly by the Aedes mosquito, causing yellow fever, dengue, chikungunya, Mayaro, West Nile, Zika, and various encephalitides (and only against yellow fever is there a vaccine, since 1937); 2) worms, spread by Aedes, Anopheles, and Culex mosquitoes, causing filariasis (elephantiasis); and 3) parasite protozoa, all species of *Plasmodium*, spread by the Anopheles mosquito and causing malaria, of which there are 450 types, five affecting humans: a) *P. knowlesi* (in southeast Asia), b) *P. ovale* and c) *P. malariae* (in West Africa), d) *P. vivax* and e) *P. falciparum* (most dangerous and widespread). The

(continued on page 22)

REVIEWS

(continued from page 21)

first three are rare and have a low mortality rate, but the mortality rate for *vivax* is 5% and that for *falciparum is* 25 to 50%. The temperature range for mosquitoes to live is 50^o to 105^{o}F, preferably above 75^{o}F. Below 70^{o}F, the reproductive cycle of the parasite is longer than the lifetime of the mosquito. Winegard describes the symptoms of yellow fever and malaria so that the reader is in the position of being infected.

But, Winegard writes, "unlike the dinosaurs . . . humans evolved to fight back [against the mosquito]." The human evolution to fight *P. falciparum* and *P. vivax* was the sickle cell gene that mutated hemoglobin to produce sickle-shaped red blood cells (instead of donut-shaped cells) that the parasite could not bind to. This gives 90% immunity against these two parasites; but in reducing the blood's ability to transport oxygen, it also lowers the average human life expectancy to 23 years. Today one in twelve African-Americans carry this gene.

Before sickle-cell immunity came Duffy negativity, absence of an antigen receptor on hemoglobin which binds *P. vivax* and *P. knowlesi* to it. All but 3% of Central and West Africans carry this mutation, whose downsides include "higher predisposition to asthma, pneumonia, and various cancers" (p. 45) and 40% greater susceptibility to HIV infection. Another abnormality in hemoglobin, thalassemia, reduces the risk of *vivax* by 50% and is most prevalent in areas surrounding the Mediterranean Sea. The G6PDD (glucose-6-phosphate dehydrogenase deficiency) modification to hemoglobin is missing protection against oxidants and provides partial immunity to *falciparum* malaria, with the only downsides coming from "triggers," such as eating fava beans and taking "antimalarial drugs such as quinine, chloroquine, and primaquine." (p. 36)

Humans and their hominid ancestors have also benefited from learning which foods, like the mululuza shrub, act as antimalarial drugs. The mululuza shrub is related to the chrysanthemum, which contains the commercial pesticide pyrethrum (effective against the nervous system of insects, including mosquitoes). This has made the chrysanthemum associated with death in cultures characterized by mosquito-borne diseases. "Cloves, nutmeg, cinnamon, basil, and onions" (p. 38) also provide relief to malaria's symptoms.

The second Chinese emperor, Shen Nung, is credited with inventing the plow and discovering medicinal herbs to make tea. Chinese tea culture dates from 2700 BCE until it was banned by the thirteenth century Mongol invasion which replaced tea with koumiss ("fermented mare's milk churned into alcohol" (p. 34)) and other beverages. Although tannic acid in tea was found to kill bacteria causing cholera, typhoid, and dysentery, the only tea with antimalarial properties is that made from *Artemesia annua* (sweet wormwood plant), which is the source of artemisinin, a very expensive basis for treating malaria today.

Describing these early remedies in the second chapter marks Winegard's transition from the role of the mosquito to her effect on history (he uses the feminine gender because only the biting female mosquitoes are responsible). He begins with Ancient Greece, noting that Hippocrates recognized malaria as the most threatening disease then known, even identifying its fever cycles (which Winegard explains in his second chapter) but associating it with water rather than mosquitoes, and observing that malaria limited how far Alexander the Great could expand his empire before dying from it on his return through Babylon. Then on to Rome, where surrounding Pontine marshes protected Rome from foreign conquest because of the malaria-causing mosquitoes they harbored.

The role of the mosquito in historical events concerning Greece and Rome is only the beginning of a recurring theme in this book: that outsiders entering an area besieged with malaria are at a disadvantage. Winegard uses the word "seasoned" to refer to those living in such an area, saying that they are "seasoned" to malaria. Today we would say that they have acquired an immunity to the disease by contracting it and recovering. This theme of stopping would-be conquerors by local malaria continues with the Crusades (a term Winegard says was not used until 1750) and the Mongol invasions under Ghengis Khan and his grandson Kublai. But warring invaders bring their own diseases with them as well as experience those of the area they wish to conquer. Winegard writes that in laying siege to Kaffa (Italy) in 1346, the Mongols brought bubonic plague to Western Europe through infected corpses they dumped.

The next example of a conquerer bring its diseases with them is what Winegard calls the Columbian Exchange. Before Columbus and his Spanish crews arrived, the Western Hemisphere was relatively disease free, largely due to its low population and few domesticated animals (in chapter two Winegard attributes human diseases to human domestication of animals – the common cold to the horse; bird flu, chicken pox, and shingles to chickens; influenza to pigs and ducks; and measles, tuberculosis, and smallpox to cows). He writes that Spanish priest Bartholome de las Casas recorded the mosquito-induced illness and mistreatment of New World natives that Columbus brought and that not only mosquito-induced malaria and yellow fever but also smallpox decimated the indigenous population by as much as 95%, leaving the land ready to occupy by European colonists who would arrive in succeeding centuries. But, in what Winegard characterizes the first experience in globalization, the Spanish did take syphilis back to Spain with them, also tobacco and coffee.

(continued on page 23)

REVIEWS

(continued from page 22)

But the deaths of indigenous New World people from Old World diseases caused the need to import replacement labor in the form of enslaved Africans to staff the agricultural operations set up by the Spaniards. The first group arrived on Columbus's final voyage, and Las Casas is reported as looking more lowly on them than he formerly did on the indigenous people of the New World. While many of the enslaved Africans were genetically immune to malaria, not all of them had acquired immunity to yellow fever.

Winegard explains in a historical aside the difference between slavery in Europe and Africa. Slaves in Europe had typically come from the classes of criminals and prisoners of war, and their period of involuntary servitude was limited. Moreover, their offspring were not regarded as slaves. But by the twelfth century European slavery had given way to serfdom, which was less onerous on landowners. Meanwhile, enslavement by African victors of those they conquered continued, and Christians and Muslims from more northerly latitudes profited from trafficking in these enslaved Africans. Winegard writes that a total of 30 million Africans were thus extracted into slavery: 15 million arrived alive in the Western Hemisphere, 10 million died *en route*, and the other 5 million were sold in Middle Eastern slave markets.

Winegard also points out that by being the first to become a colonial power in the Western Hemisphere, the Spanish gained an edge over later colonial powers in becoming "seasoned" to mosquito-borne diseases. Moreover, some of them had G6PDD or thalassemia immunity; and because of this, there is a substantial contingent of population of Spanish descent in former Spanish colonies, but a population of primarily African descent in former British, French, and Dutch colonies in the Western Hemisphere tropics. The French and British, however, did succeed in implanting their own colonists in more northerly regions of the Western Hemisphere, the French finding a niche in fur trading along the St. Lawrence River, and the British, after a rough start, in Virginia, where a profitable tobacco growing operation emerged.

Eventually the colonies of the New World sought and gained their independence, first the British North American colonies, where the colonists were "seasoned" and mosquitoes affected Britain's "southern strategy" in the years before the culminating battle at Yorktown. Also having the advantage of being "seasoned," the inhabitants of Haiti and Spanish colonies likewise overthrew the rule of France and Spain, respectively. Haiti at that time was known as Saint-Domingue and thrived with exports of sugar, cotton, tobacco, cocoa, and indigo which accounted for 35% of the French economy. The 1791 revolt led by Toussaint Louverture caused escaping French colonists to flood Philadelphia in 1793, bringing a yellow fever epidemic with them. That same year Britain sent an expedition to try to take Haiti for its own, only to have 15000 of its 23000 troops die from yellow fever and malaria and withdraw in 1798. Napoleon was no more successful in 1801, losing 55000 of his 65000 French soldiers to mosquito-borne diseases. Winegard writes that by 1826 "every Spanish American colony attained independence save Cuba and Puerto Rico." (p. 285) With Napoleon selling Louisiana to the U.S. in 1803, this ended further European efforts to colonize the Western Hemisphere. But Europe also placed an embargo on trade with Haiti, in which the U.S. joined, and this placed Haiti in a state of impoverishment, which has continued to this day.

Once the U.S. gained its independence from Britain, its population wanted to expand beyond the bounds of the East Coast and found that indigenous people were in the way. Because Britain was backing them in what was then called the Northwest Territory and also interfering with American shipping in the course of its war with Napoleon, President James Madison had Congress declare the War of 1812, but the mosquitoes in Washington, DC, didn't stop Britain from burning it. The market for tobacco became glutted, and cotton was realized to be a more profitable crop. But it required the warmer climate of the "Deep South," where the Cherokee, Creek, Chickasaw, Choctaw, and Seminole tribes lived; so President Andrew Jackson had them moved to the "Indian Territory," which is now the state of Oklahoma. Lastly, we wanted California; and, when Mexico refused to sell it, President James Polk went to war to gain it. Although some questioned the value of spending $40 million to evict the Seminole tribe from southern swamps and some felt that the Mexican War made the U.S. look like a bully, General Winfield Scott wisely *avoided* the mosquito by not getting bogged down at Veracruz on the way to taking Mexico City.

Gen. Scott put forth the same advice at the outset of the American Civil War, but dithering General George McClellan did not carry it out. Initially the stated purpose of the war was preservation of the Union, Winegard observes, but the mosquito's role in delaying it led to the realization that a new strategy was needed: freeing slaves in the seceded states. This could deprive Confederates of their workforce and provide a disease-resistant group of men who could fight for the Union. After the South was halted in their first foray into the North at Antietam, this was carried out by the Emancipation Proclamation on 1 January 1863.

In addition to this strategy change, two other factors proved important: a plentiful northern supply of quinine (which inhibits the ability of the malaria parasite to metabolize hemoglobin) and Gen. Ulysses S. Grant. Both enabled a successful siege of Vicksburg, MS, which gave the Union control of the Mississippi River and divided

(continued on page 24)

REVIEWS

(continued from page 23)

the Confederacy in 1863. This prompted Lincoln to summon Grant to launch an ultimately successful campaign through Virginia to end the war. Curiously, the 75% of 40000 deaths of African Americans due to disease was greater than the 65% of the 360,000 Union deaths, and on a par with the estimated 75% of the 290,000 Confederate deaths, thus discrediting "the scientific stereotype of African immunity to mosquito-borne disease." (p. 332)

Cuba became famous for the exports that Haiti produced before its revolution, and the U.S. acquired it in the Spanish-American War. But the presence of malaria and yellow fever precluded stationing troops there, so the U.S. granted Cuba "formal" independence in 1902, but with strings attached. Meanwhile, the mosquito was identified as the cause of malaria and yellow fever. In 1877 Patrick Manson identified the mosquito as the vector of filariasis and also suspected malaria. In 1882 Carlos Finlay identified the Aedes mosquito as the probable vector for yellow fever, which was confirmed by Walter Reed in 1893. In 1884 Alphonse Leveran identified the mosquito as the source of the malaria parasite. Ronald Ross and Giovanni Grassi identified the Anopheles mosquito as the distributor of malaria, and Robert Koch confirmed that quinine removed the malaria parasite from human blood. In 1902 William Gorgas eradicated yellow fever from Havana by controlling possible mosquito breeding grounds and fumigating with sulfur and chrysanthemum-pyrethrum as powder or as a solution in kerosene, and he did the same in 1904 for what would become the Canal Zone and enable construction of the Panama Canal. Lastly, the virus causing yellow fever was isolated in 1927, and a vaccine developed against it ten years later.

The northern latitudes of World War I minimized the effect of mosquito-borne disease, but this was not true for the Pacific theater of World War II. There Captain Theodor Seuss Geisel portrayed the Anopheles mosquito as a cartoon character named "Ann," to remind troops of the danger of malaria. Because quinine was scarce (and the malaria parasite had developed resistance to it), the synthetic atabrine (and later chloroquine) was given as treatment; and both troops and their environment were sprayed with DDT to kill mosquitoes. This combination was very effective in reducing malaria, and government efforts to control it during World War II gave rise to what eventually became the present-day Centers for Disease Control and Prevention.

But the apparent victory over malaria was short-lived. In 1961 Rachel Carson pointed out the environmental dangers of DDT in *Silent Spring*, but mosquitoes had already genetically developed a resistance to it; and the malaria parasite had developed resistance to chloroquine as well. The Chinese "rediscovered" artemisinin, but it too found resistance by 2000. Artemisinin-based Combination Therapies (ACT) are effective but also expensive. Meanwhile, AIDS has displaced malaria as the disease most in need of a cure. And the Aedes mosquito has acquired an additional repertoire of diseases it can transmit: West Nile, Zika, SARS, bird flu (H_5N_1), swine flu (H_1N_1), and Ebola.

Although the diseases caused by viruses transmitted by the Aedes mosquito pop up at all points in the world, Winegard points out that Africa bears the brunt of malaria (85% of all new cases) and two "contractually partnered and somewhat synergistic" (p. 421) diseases, AIDS (50% of new cases) and tuberculosis. He also notes that GlaxoSmithKline's RTS,S vaccine against malaria is only 39% effective after four years and 4.4% effective after seven years, with results not yet available for subsequent candidates.

Finally, Winegard brings up the ability of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats, described in our Fall 2020 issue) to alter the course of natural evolution in general and to extinguish the Aedes and Anopheles mosquitoes in particular. He leaves his readers with three questions to ponder:

1. What unintended consequences could result from using CRISPR to extinguish the Aedes and Anopheles mosquitoes?

2. If the Aedes and Anopheles mosquitoes are extinguished, will other mosquito species evolve into their roles?

3. If the Aedes and Anopheles mosquitoes are extinguished, would consequent increased population make life on Earth unpleasant due to crowding and insufficient resources?

In his Conclusion, Winegard acknowledges the role of a mosquito in bringing his great-grandparents William and Hilda Winegard together. Before concluding this review, I would like to acknowledge what seem to me to be two salient subthemes. In tracing the path of human history from the standpoint of the involvement of mosquitoes, it seems inescapable not to recognize the role played by biological evolution, not only in the ability of mosquitoes, with their short lifetimes, to develop resistance to new chemical compounds we throw at them, but also in the development of new agents with which they can transmit disease, let alone SARS-CoV-2, which has been in its second year of exercising control over the entire planet without any need for mosquitoes.

The second subtheme to which reading this book has awakened me is the unjust treatment by European Powers – and their American offshoot – throughout history, to-

(continued on page 25)

REVIEWS

(continued from page 24)

ward indigenous people, not only in Africa, but also in the Western Hemisphere. Everybody needs an equal seat at the table in addressing Winegard's three final questions.

Lastly, although Winegard has told a very powerful story in his book, I wish he had documented it more precisely. His text includes a lot of quotations, but his "Notes" are really just mini-essays giving general descriptions of sources he used in writing chapters or pairs of chapters, and there is no way to find the source of any of his specific quotations. When he writes of the rediscovery of artemisinin in chapter 18, he notes specifically that he has already cited it in chapter 2. But before he cites Hippocrates's failure to associate malaria with mosquitoes on page 66, he notes on page 54 that "In his detailed sixth-century BCE compendium on medicine, Indian physician Sushruta singled out five mosquito species of the northern Indus River Valley: 'Their bite is as painful as that of a serpent, and causes diseases . . . accompanied by fever, pain of limbs, hair standing on end, pain, vomiting, diarrhea, thirst, heat, giddiness, yawning, shivering, hiccups, burning sensations, intense cold.'" Since this pronouncement predates all the other references in Winegard's book, it made me wonder why no one apparently followed up on it and the mosquito was not identified as the cause of malaria until the end of the nineteenth century.

\- John L. Roeder

(*Editor's Note*: Biology correspondent Betty Chan has called attention to actions that have been taken in response to Winegard's questions regarding the use of CRISPR since his book was published. Emily Waltz, "First Genetically Modified Mosquitoes Released in the United States," *Nature,* **593**, 175-176 (13 May 2021) reports that in the Florida Keys British biotech firm Oxitec is releasing "bioengineered male *A. aegypti* mosquitoes, which don't bite, to mate with the wild female population, responsible for biting prey and transmitting disease. The genetically engineered males carry a gene that passes to their offspring and kills female progeny in early larval stages. Male offspring won't die, but instead will become carriers of the gene and pass it to future generations. As more females die, the *A. aegypti* population should dwindle." The Oxitec website, www.oxitec.com, reports that "On August 18th 2020 the Florida Keys Mosquito Control District (FKMCD) Board of Commissioners approved the FKMCD-Oxitec Investigational Agreement for the release of Oxitec's Friendly™ *Aedes aegypti* mosquitoes in 2021. This follows regulatory approvals for the project by the U.S. Environmental Protection Agency (EPA), U.S. Centers for Disease Control and Prevention (CDC), and seven State of Florida agencies, including the Department of Health. This project is being overseen by FKMCD, the EPA and the Florida Department of Agriculture and Consumer Services (FDACS). Independent evaluation of the project is provided by the U.S. CDC, University of Florida, Monroe County Department of Health, and local leaders, forming a broad and diverse coalition to support this effort.")

(*Editor's Note*: The following is a reassessment by Frank Lock of his review of Max Tegmark's *Life 3.0* in our Winter 2021 issue.)

This is a follow-up to a book review I wrote that was published in the Winter 2021 issue of the Teachers Clearinghouse for Science and Society Education *Newsletter*. That review was written about Max Tegmarks's book, *Life 3.0*. At the end of the review, I described how it took me two years to commit to writing the review, due to the apprehension I experienced as I read the book.

I recently read a book which has eliminated my apprehension about Artificial General Intelligence (AGI). The book is composed of three parts, the first of which is technical and presents mostly information about brain physiology leading to what the author, Jeff Hawkins, identifies as The Thousand Brains Theory of Intelligence.

I am not writing this to review the book, which is titled *A Thousand Brains*. I am writing to inform readers about information in the book that concludes that AGI should not be expected to have the innately amoral tendencies that humans, in general, have.

One important thing I learned from *A Thousand Brains* is that only mammals have a neocortex. Hawkins writes that this makes them intelligent, general purpose learners. I also learned what has been discovered about how the neocortex functions. That includes the idea that it uses models and maps to react to the information it gathers from our senses.

Hawkins writes about the evolution of mammalian brains, enabling mammals to navigate in the environment in which they reside. He describes the function of what he describes as the "old brain," separate from the neocortex, which controls our emotions, survival instinct, desire to procreate, as well as our innate and primitive behaviors. The "old brain" is adapted for short term survival.

In a chapter titled "The Existential Risk of Human Intelligence," Hawkins writes, "The old brain represents an existential threat because our neocortex has created technologies that can alter and even destroy the entire planet." He includes information indicating that equipping AGI with the equivalent of a neocortex will be possible, while replication of the "old brain" will be difficult, as well as undesirable.

(continued on pag 26)

Work of European Man Eclipses that of American Woman

Preliminary results published in 1859 by John Tyndall showed that the temperature of tubes of carbon dioxide and water vapor increased when they were exposed to infrared radiation (then called "radiant heat") but that no temperature increase was observed when tubes of oxygen, hydrogen, or nitrogen were exposed.

Three years earlier the same results had been observed by Eunice Newton Foote, who used the Sun as her source of heat, according to an article by Maura Shapiro in the *Physics Today* electronic newsletter for 23 August 2021, the 165th anniversary of a meeting of the American Association for the Advancement of Science (AAAS) at which Smithsonian Secretary Joseph Henry read the results of Foote's research. Shapiro notes, though, that Henry "failed to recognize the implications of her research on the heat-absorbing properties of carbon dioxide and water vapor." As Foote stated in the subsequent paper describing her work, "An atmosphere of that gas [carbon dioxide] would give to our earth a high temperature."

Thus the work of a European man eclipsed that of an American woman. Interestingly, Henry had experienced a similar eclipsing of his own discovery of electromagnetic induction 26 years previously. According to the *Project Physics Text*, Henry recorded his discovery of the phenomenon before Michael Faraday recorded his, but the pressure of other duties delayed Henry's publication of his discovery by a year, by which time Faraday had already published.

Clearinghouse Update

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

Coal Continues as a Threat in Germany

No sooner than we put to bed our Spring 2021 issue, focused on the phasing out of fossil fuels, did NPR run a story on the encroachment of the German countryside by surface lignite mines. The same story also notes that German courts have moved up to 2045 the deadline for zero carbon dioxide emissions, but it also cites three surface mines operated by RWE. Although RWE is also building wind farms, the story cites 2029 as the closing date for two of the lignite mines and 2038 for the third. The need for this coal is to replace the electricity generation formerly provided by the nuclear power plants Germany is shutting down. Goldstein and Qvist called attention to this problem in *A Bright Future*, profiled in our Winter/Spring 2019 issue and reviewed by Frank Lock in our Spring 2021 issue.

RESOURCES

(continued from page 19)

countries; yet it is usually the poor and disadvantaged who are most vulnerable to the consequences," she notes. "Pondering the intersection between scientific phenomena and societal inequities takes us to the heart of climate justice." She follows this with a 5E-lesson on climate justice lasting two to four class periods, within the context of and photographs taken during her own three-week visit to Madagascar.

4. Emma Refvem and Dana Haine, "Generate: The Game of Energy Choices," *Sci. Teach.,* **88**(6), 52-57 (Jul/Aug 21).

"Generate," developed and kept up-to-date by USEPA scientists, is a simulation which allows student teams to choose the energy sources to meet the needs of an electrical grid, using actual data for capital and operating costs and consequent carbon dioxide emissions. It can be done in different rounds, with teachers allowed to establish different criteria to assess the choices made by student teams in each round. All the materials needed to play "Generate" are available without charge at <https://www.epa.gov/climate-research/generate-game-energy-choices>.

5. John M. Boone and Cynthia H. McCollough, "Computed tomography turns 50," *Phys. Today*, **74** (9), 34-40 (Sep 21).

"Computed tomography (CT) uses thousands of x-ray transmission measurements taken at different angles around a patient to produce three-dimensional cross-sectional images of the human body." Characterized by these authors as "a stethoscope on steroids," it earned the 1979 Nobel Prize for Medicine or Physiology for engineer Godfrey Hounsfield and physicist Allan Cormack who invented it, and has seen much progress in its first half century of existence, to the point that a scan which once took 4.5 minutes can now be done in 5 seconds. In addition to providing noninvasive imaging of the human interior, computed tomography is also used to scan nuclear warheads and critical manufactured items in aerospace or wind turbines for imperfections as well as airport luggage for contraband.

REVIEWS

(continued from page 25)

Jeff Hawkins is the cofounder of a neuroscience research company called Numenta. Information about the company and the book can be found at <https://numenta.com>.

\- Frank Lock

The Columbia University Climate School

by Michael J. Passow
Earth Sciences Correspondent

If we are going to solve the looming climate change problems, where will the problem-solvers come from? There is a good chance many will graduate from the new Columbia University Climate School (https://climate.columbia.edu/).

In response to the immense, urgent challenges posed by climate change, Columbia University created the Climate School with a Master of Arts degree in Climate and Society. Its goals include creating an innovative, coordinated, and transdisciplinary approach to deal with current and future climate issues. The school utilizes Columbia University's strengths in basic disciplines and research, expanding resources to understand better changing climate and the impact on society. This is the first new School established as part of Columbia University in a quarter century.

The M.A. in Climate and Society will be the Climate School's first academic program. It is a twelve-month program to train professionals and academics to understand and deal with the impact of climate change and variability on society and the environment. Research discoveries and opportunities will be available through the Columbia Earth Institute and its components, the Lamont-Doherty Earth Observatory, The Center for International Earth System Information Network, the Sabin Center for Climate Change Law, the International Research Institute for Climate and Society, the Climate and Health Program, the Data Science Institute, the Centers on Global Energy Policy and for Climate System Research and Resilient Cities and Landscapes, and the R.V. *Marcus Langseth.*

Guiding principles include education and research, culture and inclusion, and impact and solutions in addition to traditional degree-earning academic programs. Climate School participants can engage in Sunday Sanity Song and Story Swaps, and "walking the walk, not just talking the talk," a program that links investors with scientists to confront climate change through Alliance Bernstein (https://news.climate.columbia.edu/2021/04/28/landmark-program-joins-investors-with-scientists-to-tackle-climate-change/).

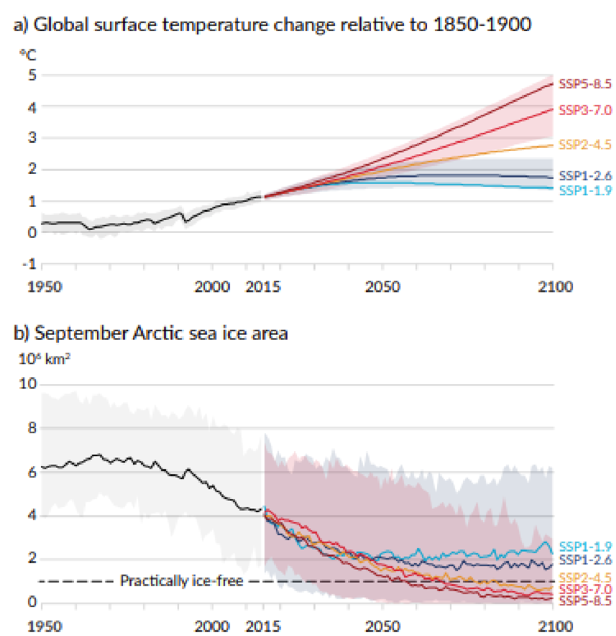
During summer 2021 selected high school students participated in the Columbia Climate School in the Green Mountains in Castleton, VT (https://precollege.sps.columbia.edu/highschool/columbia-climate-school). This 13-day, 12-night program founded on the idea that solutions to the climate crisis can be addressed through the voices of those who will be most affected — today's students. There are also online immersion programs for outstanding students (https://precollege.sps.columbia.edu/highschool/online/courses/3-week).

The initial leadership of the Climate School has been entrusted to a very distinguished quartet: (Sir) Alex Halliday, the Director of the Columbia Earth Institute; Jason Bordoff, the founding director of the Center on Global Energy Policy; Maureen (Mo) Raymo, G. Unger Vetlesen Professor of Earth and Environmental Sciences at Columbia University and director of the Lamont-Doherty Earth Observatory; and Ruth de Fries, University Professor and Denning Family Professor of Sustainable Development in the Department of Ecology, Evolution and Environmental Biology, who has played key roles in the undergraduate program in Sustainable Development at Columbia's Earth Institute.

IPCC posits five scenarios

(continued from page 28)

The emissions in these five scenarios will have the following effect on atmospheric temperature and Arctic Ice:



The Paris Climate Agreement seeks to keep global surface temperature change relative to 1850-1950 under 1.5°C, and only SSPS-1.9 achieves that goal by 2100, although it goes above that limit in the middle of the 21st century. The SSPS-2.6 scenario is the only other scenario that keeps the increase in global surface temperature under 2°C. The more likely scenario resulting from pledges by the signatories of the Paris Climate Agreement, however, is SSPS-4.5. Keeping the increase in global surface temperature under 2°C requires SSPS-1.9 or SSPS-2.6, and both of these scenarios require reducing carbon dioxide emissions to zero in the latter half of the 21st century.

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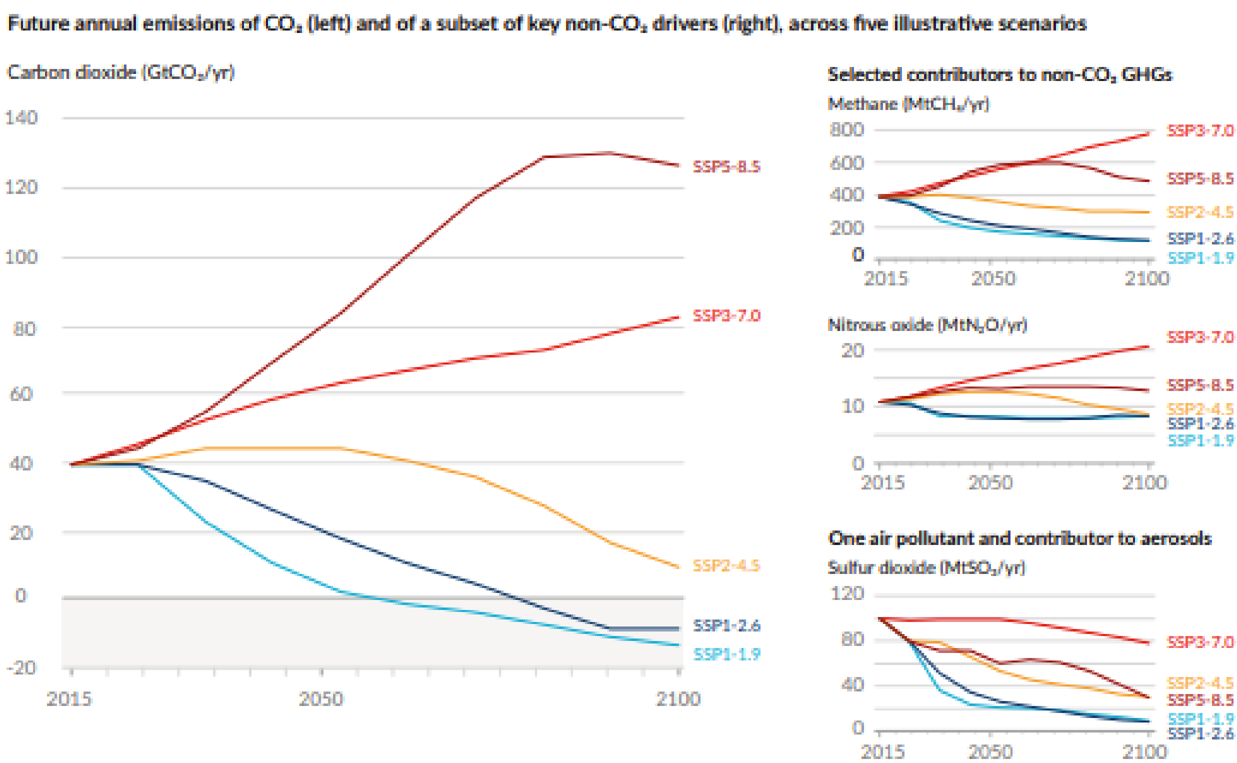
IPCC posits five scenarios

The 2021 Report of the Intergovernmental Panel on Climate Change considered five scenarios, designated by the following names and numbers: very low emissions (SSP1-1.9), low emissions (SSP1-2.6), midlevel emissions (SSP2-4.5), high emissions (SSP3-7.0), and very high emissions (SSP5-8.5). They are characterized by the following human emissions into Earth's atmosphere, as pictured in the following graphs:



(continued on page 27)