TEACHERS CLEARINGHOUSE
FOR SCIENCE AND SOCIETY EDUCATION
NEWSLETTER

Vol. XL, No. 1
Winter 2021

Engineering asks for a seat at the STEM Education Table

The Teachers Clearinghouse for Science and Society Education was founded almost 40 years ago in response to a perceived need to infuse societal topics into science courses. But shortly before our incorporation with that name in 1985 "it became fashionable to speak of Science, *Technology*, and Society," as noted in our October 1984 issue, which headlined a cover story titled "The 'T' in S/T/S: Whither Technology Education?"

For the next two decades our work was done largely in tandem with the National Association for Science, Technology, and Society (NASTS), with two of the three co-founders serving on the Board of that organization. Then the acronym STS gave way to STEM, which added Mathematics and Engineering to Science and Technology to provide a way to embrace all the fields considered by the lay public to be "technical." Accordingly, coverage in this *Newsletter* has followed this trend.

We had covered the National Research Council's *National Science Education Standards* in our Winter 1995 and 1996 issues and the American Association for the Advancement of Science's *Benchmarks for Science Literacy* in our Winter 1994 issue and would go on to cover the *Next Generation Science Standards* in our Winter/Spring 2013 issue. We also covered *Technology for All Americans* and the follow-up *Standards for Technological Literacy* from the International Technology Education Association, which became the International Technology and Engineering Educators Association in 2010, in our Winter 1999, Spring 2000, and Fall 2001 issues. (Although we have occasionally published articles about math education, we realize that our outreach to mathematics educators has been limited and have not covered their standards documents.)

Of the four stem subjects, the only one not to have its own niche in precollege education or to have its own educational standards is engineering – until now. According to the website, <p12framework.asee.org>, the American Society of Engineering Education (ASEE, originally the Society for the Promotion of Engineering Education, formed in 1883) and the Advancing Excellence in P-12 Engineering Education (AE^3) research collaborative (founded in 2018) have identified "common P-12 engineering learning goals that all students should reach to become engineering literate" in their *Framework for P-12 Engineering Learning: A Defined and Cohesive Educational Foundation for P-12 Engineering*.

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Engineering Education – a new approach to STS?

by John L. Roeder

Independently of the *Framework for P-12 Engineering Learning*, which is the cover story of this issue, Joni Lakin, Daniela Marghitu, Virginia Davis, and Edward Davis offer a way to provide an educational experience in engineering for precollege students. They do this in an article, "Introducing Engineering as an Altruistic STEM Career," in the March-April 2021 issue of *The Science Teacher*, the National Science Teaching Association journal for secondary science education.

Mindful that students may not be motivated to become engineers by reports of employment opportunities and good salaries because they are more interested in solving problems to benefit society, these authors have a developed a series of activities, which can be used stand-alone or as part of a course, to engage students collaboratively to achieve a goal to benefit society through technology. These activities are based on the fourteen *Grand Challenges for Engineering* presented by the National Academy of Engineering in 2008, which they list as follows:

1. Engineer better medicines.
2. Provide access to clean water.
3. Create tools that advance scientific discovery.
4. Enhance virtual reality.
5. Prevent nuclear terror.
6. Advance personalized learning (online or other education formats).

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Letters to the Editor

John,

When I was AIP's CEO and since retiring I have enjoyed being on your mailing list for "Teacher's Clearinghouse." You may recall that you occasionally asked permission to reprint an essay from my weekly "AIP Matters" blogs that I posted during my tenure at AIP from 2007-2015.

Soon after I retired, I was asked by an editor at Springer to compile a selection of the essays into a book. Thanks to the isolation of the pandemic shutdown, I completed the book, "Scientific Journeys" and it was published by Springer two weeks ago (https://www.springer.com/us/book/9783030557997).

I think both you and your audience would enjoy it.

Best regards,

Fred

(*Editor's Note*: Springer's publicity for Fred Dylla's *Scientific Journeys: A Physicist Explores the Culture, History and Personalities of Science* describes the book as "An engaging collection of stories about events and personalities that shaped a physicist's world view." It continues as follows:

> This collection of essays traces a scientific journey bookmarked by remarkable mentors and milestones of science. It provides fascinating reading for everyone interested in the history, public appreciation, and value of science, as well as giving first-hand accounts of many key events and prominent figures. The author was one of the "sputnik kids" growing up in the US at the start of the space age. He built a working laser just two years after they were first invented, an experience that convinced him to become a physicist. During his 50-year career in physics, many personalities and notable events in science and technology helped to form his view of how science contributes to the modern world, including his conviction that the impact of science can be most effective when introduced within the context of the humanities - especially history, literature and the arts. ***From the Foreword by former U.S. Congressman*** [and present CEO of AAAS] ***Rush D. Holt:*** *In this volume, we have the wide-ranging thoughts and observations of Fred Dylla, an accomplished physicist with an engineer's fascination for gadgets, a historian's long perspective, an artist's aesthetic eye, and a teacher's passion for sharing ideas. Throughout his varied career [...] his curiosity has been his foremost characteristic and his ability to see the connection between apparently disparate things his greatest skill. [...] Here he examines the roots and growth of innovation in examples from Bell Laboratories, Edison Electric Light Company, and cubist painter Georges Braque. He considers the essential place of publishing in science, that epochal intellectual technique for learning how the world works. He shows the human enrichment and practical benefits that derive from wise investments in scientific research, as well as the waste resulting from a failure to embrace appropriate technologies.*

Among the essays included are "Literature and Legacy Flow Along the Rhine," "Invention and Discovery: Fleming and Edison," "Rutherford's Nuclear World," "Fueling Science for War and Peace," and "Shelter Island's Famous Physicists.")

IN THIS ISSUE

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>.

Horizon Surveys Science and Math Education

Horizon Research, Inc. has been commissioned by the National Science Foundation to gather data for and publish six editions of the *National Survey of Science and Mathematics Education (NSSME)* – in 1977, 1985-86, 1993, 2000, 2012, and 2018. The most recent survey, produced by E. R. Banilower, P. S. Smith, K. A., Malzahn, C. L. Plumley, E. M. Gordon, and M. L. Hayes, bears the acronym *NSSME+* because it adds a focus on computer science education as well.

The *NSSME+* asked the following questions:

1. To what extent do computer science, mathematics, and science instruction reflect what is known about effective teaching?

2. What are the characteristics of the computer science/ mathematics/science teaching force in terms of race, gender, age, content background, beliefs about teaching and learning, and perceptions of preparedness?

3. What are the most commonly used textbooks/ programs, and how are they used?

4. What influences teachers' decisions about content and pedagogy?

5. What formal and informal opportunities do computer science/mathematics/science teachers have for ongoing development of their knowledge and skills?

6. How are resources for computer science/mathematics/ science education, including well-prepared teachers and course offerings, distributed among schools in different types of communities and different socioeconomic levels?

And it gathered data from three school-level questionnaires (from the school coordinator and about the science and mathematics programs) and three teacher-level questionnaires (from mathematics, science and high school computer teachers).

The bulk of the first chapter describes the sampling methods used to insure that the survey accurately represented the entire U.S. The content of the remaining chapters is highlighted as follows:

"Chapter Two focuses on teacher backgrounds and beliefs. Basic demographic data are presented along with information about course background, perceptions of preparedness, and pedagogical beliefs. Chapter Three examines data on the professional status of teachers, including their opportunities for continued professional development. Chapter Four presents information about the time spent on science and mathematics instruction in the elementary grades and about course offerings at the secondary level. Chapter Five examines the instructional objectives and the activities used to achieve these objectives, followed by a discussion of the availability and use of various types of instructional resources in Chapter Six. Finally, Chapter Seven presents data about a number of factors that are likely to affect science, mathematics, and computer science instruction, including school-wide programs, practices, and problems."

What follows are excerpts from those chapters, as indicated by enclosures in quotation marks, with references to the many tables (which comprise the bulk of the report) deleted.

Chapter 2. "Teacher Background and Beliefs"

"*Teacher Characteristics*. The vast majority of science teachers at the elementary level are female. The proportion of science teachers who are female decreases as grade level increases, to about 60 percent at the high school level. Science teachers' experience teaching any subject at the K–12 level is similar across grade ranges, though middle school science teachers tend to be less experienced teaching science and more likely to be new to their school." The majority of the science teaching force is between age 30 and 50, "with roughly 25 percent of science teachers in each grade range being older than 50. Fewer than 20 percent are age 30 or younger. Black, Hispanic, and Asian teachers continue to be underrepresented in the science teaching force. At a time when only about half the K–12 student enrollment is White and non-Hispanic, the vast majority of science teachers in each grade range characterize themselves that way."

"Analyses were conducted to examine how teachers are distributed among schools — for example, whether teachers with the least experience are concentrated in high-poverty schools (*i.e.*, schools with high proportions of students eligible for free/reduced-price lunch). Science classes in high-poverty schools are more likely than those in low-poverty schools to be taught by teachers with five or fewer years of experience. In addition, a majority of computer science classes in high-poverty schools are taught by those with only two or fewer years of experience teaching the subject." Moreover, classes with the largest percentage of students from race/ ethnicity groups historically underrepresented in STEM are more likely to be taught by teachers from these groups.

"*Teacher Preparation*. In order to help students learn, teachers must themselves have a firm grasp of important ideas in the discipline they are teaching. Because direct measures of teachers' content knowledge were not feasible in this study, the survey used a number of proxy measures, including teachers' major areas of study and courses completed. Very few elementary teachers have college or graduate degrees in science or mathematics. The percentage of teachers with one or more degrees in

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How Parents can teach Young Children about Sound

by Bernice Hauser
Primary Education Correspondent

Parents have always been out *first* educators, and during this pandemic, many parents and educators have formed a supportive alliance, each one filling in for the other in helping the young child navigate the vicissitudes of life and provide new experiences and exploration to increase the child's understanding of how the world works.

Let's share some investigations to teach young children about sound that do not involve great expense or major equipment or extra space but would be both appropriate for the early childhood classroom as well as home activities and experimentation.

First Exploration:

Have a young child sit in any and then every room in your house or your apartment. Have the young child close his/her eyes. Have the child tell you any and every sound that he/she hears. Have the child identify the source of the sound he/she described. Record the responses – I favor large notepads because they are easy to refer to later.

Inquire which room was the quietest? Which room was the noisiest? Use these responses to encourage further discussion. Was one room noisier because its windows faced the street, or because it had no heavy drapes to muffle the sound? Accept any response – and further the inquiry by responding with open ended comments to encourage additional thoughts and responses. Always be aware of your child's interest and attention level. Let the child take the lead! There is no timetable set for these explorations. Each household is different and each child is unique. But having a designated space where he/she could see his/her responses displayed, perhaps with a drawing of a leaky faucet, a whistling tea kettle, the microwave in motion, the washing machine in use, or the TV blasting always enhances the experience for young children.

Second Exploration:

Take a stroll with the child down the main street of your neighborhood or community. Stop at specific intersections and ask the child to close his/her eyes and share any and every sound he/she hears. Then follow up by directing the child to the site that the sound was coming from – *e.g.*, the garbage trucks picking up trash, a motorcycle roaring down the street, an ambulance screeching away, an airplane flying low. Document all the responses from the child and display the responses for follow-up discussions. Perhaps ask the child if he or she wishes the adult to take photos of the documented sources of noise on this excursion.

Third Exploration:

Talk a walk in a park or in a rural wooded area. Have the child begin with eyes open, senses alert, and then close his/her eyes for a minute to see if it makes a difference in what he/she hears. Again keep records, document all responses and display them as it is important to validate the child's initial reactions. Good discussions and questions help clarify whether the child is absorbing and integrating these experiences into a meaningful body of knowledge.

Fourth Exploration:

Ask the child how many sounds he/she can make? Also ask which sounds the child likes and dislikes. Examples can be laughing, crying, shouting, singing, whistling, clapping, tapping, clicking, stomping, marching, and dancing – sounds made with the mouth, hands, and feet.

Fifth Exploration:

Wash two plastic cups or yogurt containers and measure thin string to cover the distance from you and your child plus extra string to tie knots. Make a very small hole in the bottom of each cup. Thread the string through both holes and tie it in a knot so it is firmly inside each cup. Stand well apart and keep the string stretched tightly. Have your child place his/her cup so that it covers one ear. Place your cup close against your face and talk into it in a soft voice. When you talk, keep the cup close against your face. Ask your child what she/he heard. Explain that the cups act like a telephone transmitter and receiver, with the string carrying the sound of your voice and that it works because the solid object (string) carries sounds better than air.

Enrichment Activities:

Explore musical instruments or make a musical instrument. For young children, smashing two pan lids together always proves a source of joy. Using a ruler to tap on different surfaces such as metal, glass, wood, plastic, concrete, or marble can lead to simple discussions of materials that alter sound.

One musical instrument that can be made is a bottle organ, described in the reference below by Janice Van Cleave. This demonstrates how the height of an air column affects the pitch of the sound produced. You need a set of identical small mouthed bottles (Van Cleave suggests six), and a metal spoon. Put different amounts of

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The National Courts and Science Institute

by Michael J. Passow
Earth Sciences Correspondent

Very few federal or state judges have a technological or scientific background, so when scientific and technical issues come before a court, where can they turn for the understanding needed to reach a sound decision? The first and best resource designed specifically for the judiciary is the National Courts and Sciences Institute (NCSI), the American Home for Judicial Training in Science & Technology (https://www.courtsandsciences.org/). Its stated mission is to enhance the capacity of courts to resolve complex cases involving novel scientific and technical evidence, thereby contributing to the public confidence in and independence of the judicial branch of the government.

The NCSI is a 501(c)(3) public charity with two primary foci: (1) orienting judges in general principles of science, technology, and data to assist in determining the weight of evidence submitted in trials, and (2) training judges to be resources within their jurisdictions in six concentration areas. These areas of concentration include

1. Developmental Neurobiology, Risk Measures, and Issues
2. Health-Care Outcomes Research as Evidence
3. Genetic Engineering and Biotechnology
4. Molecular and Comparative Forensics in Criminal and Civil Cases
5. Ecosystem and Climate Sciences
6. Scientific Method, Tools, and Measures - Distinguishing accepted science from bogus and junk science.

As your Earth Sciences Correspondent, I will focus on Ecosystem and Climate Sciences. The NCSI helps judges learn to understand how to recognize valid research on environmental issues and to acquire the analytical tools to recognize and discount misleading or inflated claims. This is of particular value when handling cases involving environmental remediation with a major focus on microbial biotechnologies.

To become an NCSI-certified science and technology resource judge, one must commit to 60 contact hours in each of the six concentrations above, including one national workshop, quarterly on-line workshops, and a culminating practice seminar. Certification qualifies judges to serve and train their home courts, and to mentor other judges with novel evidence in complex cases. Tuition and costs are covered by home courts or financed through grants given by NCSI.

How are judges selected for NCSI programs? In some cases, judges apply for training, or may be selected by their jurisdictions. Science and technology advisers audition for appointments, and must demonstrate independence and neutral, world-class instruction abilities. Career "expert witnesses" are not welcomed. NCSI tries to avoid providing model rulings or verdicts and prohibits adjudication prescriptions.

The origin of the NCSI dates to when some 4000 judges in the U.S. and sixteen other nations received training provided by the Einstein Institute of Science Health and the Courts (EINSHAC) concerning the science, legal, and ethical implications of the Human Genome Project the last decade of the twentieth century. Much of the financial support came from a grant awarded by the U.S. Department of Energy's Bureau of Biological and Environmental Research. A separate agreement with the National Institute of Environmental Health Sciences supported extended workshops that dealt with the science and biotechnology instruction beyond the Human Genome Project.

EINSHAC evolved into the Advanced Science and Technology Adjudication Resource (ASTAR), with considerable support from bipartisan resolutions passed by the House of Representatives and Senate, and from the U.S. Department of Justice. Nearly 500 judges were ASTAR-certified following successful completion of a 120-hour general curriculum in case-related scientific method, topics and issues. This program came to an end after the Federal budget sequester of 2011 and concluded in 2013. As federal funding dried up during the Obama administration, ASTAR evolved into the NCSI and became a DC-based charity. This evolution enabled NCSI to aspire to sustainable funding through both public and private resources to continue its mission.

The NCSI has issued reports, such as the *Judges' Forecasts and Preferences for Managing Scientific Evidence in Complex Cases 2020 – 2030: Report of a Survey of State and Territorial Courts* in October 2020, and the *Neurobiology of Violence*, a scholarly journal-like compendium online. Examples of training programs include a preview of molecular trace analysis forensics, held at the National Institute of Standards and Technology in Boulder, CO, and a "Working Conversation on Developmental Neurobiology, Risk Measures, and Racism in the Working of the Courts," conducted at the St. Louis University School of Law.

A principal NCSI partner, the Bryson Center for Judicial Science Education at the University of North Carolina at Chapel Hill, has been joined in the past two years by the Woese Institute for Genomic Biology at the University of Illinois, Urbana; the Medical University of South Carolina, Charleston; the Metropolitan State University in Denver; and the Boys Town National Research Hospital, Nebraska.

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teach about Sound

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water into each bottle and gently tap each bottle with the metal spoon. When you listen to the pitch of the sound produced in each bottle, you should notice that the bottle with the most water produces the highest pitch.

If you are musically inclined, you can apportion the amounts of water in each bottle so that tapping the bottles can play a simple song. If the bottles have uniform cross section, the pitch from a bottle half filled with water is an octave higher than that of an empty bottle. The pitch from a bottle a third full of water is a fifth higher than that of an empty bottle, and the pitch from a bottle a fifth full of water is a third higher than that of an empty bottle. These fractions are higher for bottles that narrow at the top.

Van Cleave gives the following explanation: "Sounds are made by vibrating objects. The number of times the object *vibrates* — moves back and forth — is called the *frequency* of the sound. As the frequency increases the *pitch* of the sound gets higher. Tapping on the bottles causes the air to vibrate. The shorter column of air above the water vibrates faster, producing a higher pitch. As the height of the air column increases, the pitch of the sound gets lower."

<u>*Classroom Activities You Can Simulate At Home*</u>:

I recently saved and washed three red plastic Maxwell House coffee containers with their black plastic lids to give to a nursery Montessori school where a teacher of threes-year-olds was devising some simple explorations. Laying an assortment of materials on a table — marbles, paper clips, small rocks, pencils, straws, plastic forks, metal forks, tongue depressors, crayons, he invited the young students to place one item into each of the Maxwell House Containers. One student shook the container, another tapped on the container and a third tapped on the lid with a pencil. After each exploration, the teacher initiated a discussion about the sound produced.

The instructor then cut up a plastic balloon and fitted it across the opening, substituting it for the plastic lid. It was secured with a rubber band. The students repeated the above explorations to see if any differences occurred. A fun activity is to sprinkle dry cereal on the drumhead and see the cereal move (vibrate) as you tap the rubber lid.

Taking the opportunity to initiate a discussion of drums, the teacher produced the drum that is used frequently in the classroom for rhythmic exercises. A discussion about drums ensued and the teacher then arranged for the students to attend a practice session of the middle school orchestra.

Another instructor requested a tour of the maintenance department. She wanted the students to hear a hammer hitting a nail into a wooden chair, a screw driver securing a screw into place, a saw cutting up some strips of wood for a school production, *etc*. Her focus was which tool was noisy, which tool was quiet.

<u>*Vocabulary Building*</u>:

Discover the sounds that animals_make to enlarge the child's vocabulary: frogs croak, kittens purr, dogs bark, bees buzz, whales sing, dolphins click and whistle, snakes rattle, birds tweet (or you could sing "Old MacDonald Had a Farm").

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Courts and Science Institute

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Acknowledgement: I thank my high school classmate, the Hon. John Leventhal, Associate Justice, Appellate Division of the Supreme Court of the State of New York, for bringing the NCSI to my attention; and Franklin Zweig and David Yaffe for editorial improvements.

The focus of our
Spring 2021 issue will be

"The Phasing Out of Fossil Fuels"

Watch for it!

Engineering

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In giving their motivation for developing this *Framework* its authors write that "When given the opportunity to engineer, students of a variety of ages and backgrounds are motivated to learn and eager to engage in solving difficult problems. . . . Yet there has been little to no interest from the educational community in adopting engineering as central to the educational experience of every child." (p. 1) Rather, engineering education has been subsumed under science education except for the few who benefit from career education. The authors continue that "This framework is for those . . . who value engineering for the sake of engineering" (p. 1) and it has been developed to ensure "that every child is given the opportunity to think, learn, and act like an engineer." (p. 4)

Martha Cyr, Chair of the Standards Committee of the ASEE Commission on P-12 Education, welcomes readers by writing "I am pleased that you have decided to read this document" (p. 2) and goes on to relate her efforts on behalf of engineering education, which began 25 years ago and have culminated in collaboration with the other authors of this *Framework*. They write that, in order to achieve engineering literacy before graduating high school, each senior should have "experiences [which is more than just understandings] necessary to (1) orient their ways of thinking by developing *Engineering Habits of Mind*; (2) be able to competently enact . . . *Engineering Practices*; and (3) appreciate, acquire, and apply appropriate *Engineering Knowledge*." (p. 5) They then elaborate on what they call the "three dimensions" of Engineering Learning as follows:

Engineering Habits of Mind:

- Optimism: belief "that things can always be improved" (p. 5)
- Persistence: being willing to reiterate and try again
- Collaboration: ability to listen, think, and share ideas
- Creativity: identifying new patterns imagining new ways to do things, applying knowledge and experience in new ways
- Conscientiousness: considering the ethical consequences of proposed solutions
- Systems Thinking: awareness of consequences of proposed connectedness of systems

Engineering Practices:

- Engineering Design: iterative process of developing solutions to engineering problems
- Material Processing: transforming materials into devices that solve engineering problems
- Quantitative Analysis: "collecting and interpreting quantitative information" (p. 7)
- Professionalism: living up to standards, correlates with Conscientious habit of mind

Engineering Knowledge:

- Engineering Sciences
- Engineering Mathematics
- Engineering Technical Applications

The *Engineering Practices* are further broken down by what the *Framework* calls "core principles":

- Engineering Design: Problem Framing (evaluating tradeoffs among alternatives), Information Gathering (collecting and evaluating data from a variety of sources), Ideation ("generating multiple innovative ideas" (p. 31)), Prototyping, Decision-Making, Project Management, Design Methods, Engineering Graphics, and Design Communication
- Material Processing: Manufacturing (designing production efficiently), Measurement and Precision (making precision measurements prior to manufacturing), Fabrication (putting things together efficiently), Material Classification (choosing most appropriate materials), Casting/Molding/Forming (shaping materials), Separating/Machining, Joining, Conditioning/Finishing, and Safety
- Quantitative Analysis: Computational Thinking (designing and using software to visualize and control physical systems), Computational Tools ("selecting and using . . . appropriate computational tools" (p. 32)), Data Collection, Analysis & Communication, System Analytics ("analyzing an engineering system" (p. 32)), Modeling and Simulation (making and using models to simulate and evaluate design ideas)
- Professionalism: Professional Ethics, Workplace Behavior/Operations ("establishing the appropriate work culture among team members" (p. 33)), Honoring Intellectual Property, Technological Impacts ("analyzing the potential impacts of . . . decisions" (p. 33)), Role of Society in Technological Development, Engineering Related Careers (for personal career development)

The *Framework* states that the first two dimensions (habits, practices) "should be deemed as 'core' . . . to achieve *Engineering Literacy*," (p. 21) but that the third (knowledge) "should be viewed as auxiliary," (p. 21) drawn upon as needed to solve problems. The topics of Engineering Knowledge are enumerated as follows:

- Engineering Science: Statics, Mechanics of Materials, Dynamics, Thermodynamics, Fluid Mechanics, Heat Transfer, Mass Transfer and Sepa-

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ration, Chemical Reactions and Catalysis, Circuit Theory

- Engineering Mathematics: Algebra, Geometry, Trigonometry, Statistics, Probability, Calculus
- Engineering Technical Applications: Mechanical Design, Structural Analysis, Transportation Infrastructure, Hydrology, Geotechnics, Environmental Considerations, Chemical Applications, Process design, Electrical Power, Communication Technologies, Electronics, Computer Architecture

"By the end of secondary school one would not expect a student to fully understand the entirety of these areas in depth. But to be engineering-literate individuals, they should be able to deploy their engineering practices and engineering habits of mind to acquire and apply the knowledge necessary to complete engineering tasks." (p. 34)

The vision of this *Framework* is the achievement of "Engineering Literacy for All," (p. 18) as described in terms of the achievement of the aforementioned three dimensions of Engineering Learning. Like science literacy, engineering literacy is championed for all because of its importance to being a good citizen.

Underlying the *Framework* are three major principles (p. 9):

1) "access to, and equity of, engineering learning experiences."
2) "consistency and coherency of . . . engineering learning objectives . . . ."
3) "authenticity and depth in the engineering habits, knowledge, and practices that are taught . . . ."

The *Framework* readily recognizes that the equity in the first principle is not a reality for all socioeconomic groups and devotes an entire chapter to dealing with it. The present paucity of dedicated engineering courses makes it difficult to evaluate the *Framework* according to the second principle. But, as the authors point out in their motivation to develop this *Framework*, presenting engineering with authenticity and depth in precollege education requires a lot of work to be done.

The *Framework* points out that the world is full of problems calling for engineering solutions, and we must train the engineers to solve them. Although the *Next Generation Science Standards* call for teaching engineering design, this is only one of the engineering practices and not an authentic presentation of engineering. The *Framework* laments that most educational curricula spend far more time teaching about the natural world than the human-made world. Engineering at precollege levels of education doesn't receive as much attention as other STEM disciplines, they regret.

The *Framework* also objects that some schools have used STEM as a "buzzword" to cover over, typically as "robotics, science fairs, and coding," often at the extra-curricular level that is looked at as "a fun reprieve from 'education [business] as usual.'" (p. 17) "This dilution of STEM education, from a national perspective, prohibits its ability to enact transformative change and prepare the citizens needed to solve the evolving societal challenges," (pp. 17-18) the authors counter. Yet, by "calling upon scientific knowledge, mathematical truths, and technological capabilities to develop and optimize solutions to societal, economic, and environmental problems," (p. 18) they point out that engineering is positioned to play a fundamental role *integrating* the STEM disciplines.

Additionally, the *Framework* advocates "build[ing] upon children's natural problem-solving abilities" (p. 8) (but persuading them to use systematic engineering approaches), "leverage[ing] making [things] as a form of active learning," (p. 8) and connecting students with real-world problems that reflect their "interests, culture, and expectations." (p. 8) It uses this last idea as the basis for the chapter on "Diversity, Equity, and Inclusion throughout P-12 Engineering Learning," which is essential to achieve the goal of "engineering literacy for all" and to maximize the technological capability of our work force. The *Framework* also notes that without equity "history has shown that new technologies benefiting one part of society sometimes have less fortunate effects on others." (p. 40)

This chapter of the *Framework* observes that creating a socially relevant or culturally situated engineering activity is analogous to solving an engineering problem itself. It begins with knowing the interests and cultures of the students. Teachers can enhance success by facilitating the problem solving at the beginning, as students increase their confidence.

An example lesson on "Engineering the Reduction of Food Waste" is presented, focused on the concepts of "Problem Framing" and "Project Management" from the engineering practice of "Engineering Design" – a socially relevant problem that relates food to culture. The 5E (Engage, Explore, Explain, Engineer, Evaluate) template of Appendix B is used to present it.

As has been pointed out at the beginning of this article, engineering is the only STEM discipline "not to have its own niche in precollege education." When it became fashionable to use the STEM acronym to refer collectively to "technical" fields, only science, mathematics, and technology had a seat at the table in planning precollege education. More than once the *Framework for P-12 Engi-*

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neering Learning takes note of this and adds that engineering has not been invited to this table. Instead, it has been hoped that such measures as teaching engineering design and robotics clubs would suffice to develop engineering literacy before college. In this *Framework* the community of engineering educators is saying that this is not enough and asking that they be granted a seat at the STEM precollege education table. Moreover, because engineering draws from science, math, and technology, it is presenting itself as being in a position to provide true integration to all the STEM disciplines.

But in seeking a seat for engineering education at the STEM precollege education table, this *Framework* is asking only to be seated as one of four equals and looks for ways to work harmoniously with the other three STEM disciplines. The *Framework* recognizes that it must stand alongside similar documents in the other STEM fields and complement them. In particular, it compliments *A Framework for K-12 Science Education* for "a commendable job describing *engineering design practices*," (p. 21), noting that while "engineering learning is much more," (p. 21) limiting the engineering practices to engineering design should suffice for elementary students, with the remaining practices added at the middle and high school level. In suggesting how to do this, the *Framework* seems to be attempting to forge a partnership with the other STEM fields by saying that it "should support other fields in providing depth in engineering learning experiences while scaffolding toward more authentic and informed engineering practice." (p. 55) It also supports the way the standards documents from other STEM fields address the science, math, and technical applications that engineering draws from to constitute engineering knowledge. But because habits take time to form, the engineering habits of mind should be an ingrained part of STEM education from the beginning (and not be taught in dedicated lessons).

The *Framework* repeatedly states that it does not delineate performance expectations for separate grade bands as students progress toward the goal of engineering literacy in grade 12. This is because it wants to enable educational entities to be flexible "to develop performance expectations, engineering learning progressions, standards, curricula, instruction, assessment, and professional development" (p. 13) as well as to tailor the choices of engineering knowledge to the needs of their students. Yet, it recognizes that implementing a program to develop its vision of engineering literacy requires a set of "grade-band specific guides," which "will be developed," (p. 52) expectedly at the early childhood, elementary, middle and high school levels.

The *Framework for P-12 Engineering Learning* is accessible online at <p12framework.asee.org>.

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science or mathematics increases with increasing grade range, with 79 percent of high school science teachers and 55 percent of high school mathematics teachers having a major in their discipline. If the definition of degree in discipline is expanded to include degrees in science/mathematics education, these figures increase to 91 percent of high school science teachers and 79 percent of high school mathematics teachers. Only about one in four computer science teachers have a degree in computer engineering, computer science, or information science, and very few have a degree in computer science education."

"The vast majority of science teachers at each level have had coursework in the life sciences, and 59–72 percent have had coursework in Earth/space science. In contrast, in chemistry and physics, the percentage of teachers with at least one college course in the discipline increases substantially with increasing grade range. Few teachers at any grade level have had coursework in engineering. Middle school life science/biology teachers are far more likely to have a degree in their discipline (40 percent) than those teaching Earth science (five percent) or physical science (seven percent). In addition, a majority of middle school Earth science and physical science teachers have had either no coursework in the field or only an introductory course. High school biology teachers also tend to have particularly strong backgrounds in their discipline, with 63 percent having a degree in biology, and another 25 percent with at least three college courses beyond introductory biology [the comparable percentages in chemistry and physics are 42 and 24, respectively]. In contrast, about one-third of high school environmental science teachers and roughly one-quarter of Earth science teachers in each grade range have not had any college coursework in their field."

"Additional analyses were conducted to examine the extent to which teachers with the strongest background in their field are equitably distributed. Classes composed of high-achieving students are significantly more likely to be taught by teachers with strong content background than those with low levels of prior achievement. In addition, classes in schools with the highest proportion of students eligible for free/reduced-price lunch are less likely to be taught by teachers with substantial background in the subject. There also appear to be regional differences, as classes in the Northeast and Midwest are more likely to be taught by teachers who have a degree or at least three advanced courses in the subject."

"Teachers were also asked about their path to certification. Elementary science teachers are more likely than those at the high school level to have had an undergraduate program leading to a bachelor's degree and a teaching

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credential, and high school science teachers are more likely than their elementary school counterparts to have completed a post-baccalaureate credentialing program that did not include a master's degree. Similar patterns are seen among mathematics teachers' paths to certification across grade ranges, though the differences are not as striking. Seven percent of high school mathematics teachers and the same proportion of high school science teachers have not earned a teaching credential. Thirty-eight percent of high school computer science teachers have earned a teaching credential through an undergraduate program leading to a bachelor's degree, and 24 percent through a post-baccalaureate credentialing program that did not include a master's degree. Sixteen percent of computer science teachers have not earned a teaching credential."

"*Teacher Pedagogical Beliefs*. Teachers were asked about their beliefs regarding effective teaching and learning. It is interesting to note that elementary, middle, and high school science teachers have similar views about a number of elements of science instruction. At least 90 percent of teachers in each grade range agree that (1) teachers should ask students to support their conclusions about a science concept with evidence; (2) students learn best when instruction is connected to their everyday lives; (3) students should learn science by doing science; and (4) most class periods should provide opportunities for students to apply scientific ideas to real-world contexts. A similarly large proportion of science teachers in each grade range believe that most class periods should provide opportunities for students to share their thinking and reasoning."

"There are inconsistent views in relation to a number of elements of effective science instruction, with teachers agreeing with statements associated with both traditional and reform-oriented beliefs. Approximately three-fourths of teachers at each grade range agree that it is better to focus on ideas in depth, even if it means covering fewer topics, one of the central tenets of calls for reform in science instruction. At the same time, despite research on learning that suggests otherwise, roughly one-third of science teachers at each grade level agree that teachers should explain an idea to students before having them consider evidence for that idea, and more than half that laboratory activities should be used primarily to reinforce ideas that the students have already learned. And despite recommendations that students develop understanding of concepts first and learn the scientific language later, 66–77 percent of science teachers at the various grade ranges think that students should be given definitions for new vocabulary at the beginning of instruction on a science idea. Teachers of classes composed of students characterized as mostly low prior achievers are somewhat more likely to hold traditional beliefs and slightly less likely to hold reform-oriented beliefs about science instruction. Science classes in schools with the highest proportions of students eligible for free/reduced-price lunch are more likely to be taught by teachers with more traditional beliefs than those in low-poverty schools, though the difference is small."

"*Teachers' Perceptions of Preparedness*. Science teacher preparedness tends to increase with increasing grade range. For example, only 23 percent of elementary teachers feel very well prepared to develop students' conceptual understanding of science ideas, compared to 42 percent of middle grades teachers and 58 percent of high school teachers. Elementary teachers are typically assigned to teach multiple subjects to a single group of students, including not only science and mathematics, but other areas as well. However, these teachers do not feel equally well prepared to teach the various subjects. Although 73 percent of elementary teachers of self-contained classes feel very well prepared to teach mathematics — slightly lower than the 77 percent for reading/language arts — only 31 percent feel very well prepared to teach science, and only six percent feel very well prepared to teach computer science or programming. Moreover, elementary teachers are more likely to feel very well prepared to teach life science and Earth science than they are to teach physical science. Engineering stands out as the area where elementary teachers feel least prepared, with only 3 percent feeling very well prepared to teach it at their grade level, and 51 percent noting that they are not adequately prepared."

"Secondary science teachers were also asked about their preparedness to teach engineering, regardless of the discipline of their designated class. Very few middle and high school science teachers feel very well prepared to teach engineering concepts, and sizeable proportions indicate being not adequately prepared. This finding is not surprising given that few teachers have had college coursework in engineering and engineering has not historically been part of the school curriculum. K–12 teachers will likely need both high-quality curriculum and substantive professional development to be successful at integrating engineering into their science teaching." Another notable finding is that "science teachers, regardless of grade level, tend to feel less well prepared for finding out what students already know or think about the key science ideas to be addressed, and anticipating what students might find difficult in the unit."

<u>Chapter 3. "Science, Mathematics, and Computer Science Professional Development"</u>

"*Teacher Professional Development*. One important measure of teachers' continuing education is how long it has been since they participated in professional development. With the exception of elementary science teachers, roughly 80 percent or more of science, mathematics, and

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computer science teachers have participated in discipline-focused professional development (*i.e.*, focused on science, mathematics, computer science content or the teaching of science, mathematics, computer science) within the last three years. Elementary science teachers stand out for the relative paucity of professional development in science or science teaching, with fewer than about 60 percent having participated in the last three years."

"Although some involvement in professional development may be better than none, a brief exposure of a few hours over several years is not likely to be sufficient to enhance teachers' knowledge and skills in meaningful ways. Accordingly, teachers across all subject areas were asked about the total amount of time they have spent on discipline-focused professional development in the last three years. About a quarter of middle school and about a third of high school science teachers have participated in 36 hours or more of science professional development in the last three years; very few elementary teachers have had this amount of professional development in science."

"The data were also analyzed by a number of class and school equity factors. In science, classes composed of mostly low prior achievers and classes with the highest proportion of students from race/ethnicity groups historically underrepresented in STEM are significantly less likely than classes of high prior achievers and few students from these race/ethnicity groups to be taught by teachers who have participated in more than 35 hours of professional development in the last three years. A similar disparity exists by school size. Only about half as many science classes in the smallest schools compared to classes in the largest schools have access to teachers who have participated in a substantial amount of professional development."

"Teachers who had recently participated in professional development were asked about the nature of those activities. For each subject/grade-range combination, workshops are the most prevalent activity, with roughly 90 percent of teachers indicating they have attended a program/workshop related to their discipline. Participation in professional learning communities is the next most prevalent activity, especially for secondary teachers (ranging from 55–68 percent of teachers)."

"*Professional Development Offerings at the School Level.* Science and mathematics program representatives who indicated that workshops have been offered locally in the last three years were asked about the extent to which that professional development emphasized each of a number of areas. In both science and mathematics, about 60 percent of schools indicated that locally offered workshops have emphasized deepening teachers' understanding of: (1) state standards, (2) how science/mathematics is done, and (3) science/mathematics concepts. Learning how to engage students in doing science/mathematics, how to use particular instructional materials, and how to use technology in instruction are also relatively common emphases (45–54 percent of schools depending on subject). Relatively few locally offered workshops have focused on how to develop students' confidence that they can successfully pursue careers in the discipline, how to connect instruction to career opportunities, and how to incorporate students' cultural backgrounds into instruction."

"Although there is general agreement that teachers can benefit from participating in professional development workshops and study groups, it is often difficult to find time for them to do so. School representatives were given a list of ways in which time might be provided for teachers to participate in professional development, regardless of whether it is offered by the school, and asked to indicate which are used in their school. Roughly half of schools use teacher work days during the school year for science-related professional development; over two-thirds do so for mathematics-related professional development. It is less common for schools to use substitute teachers or early dismissal/late start for students as a means to provide time for professional development in science and mathematics."

"Although most schools have both teachers/coaches and administrators provide coaching, it appears that teachers/coaches are responsible for the bulk of it. In science, 40 percent of schools have teachers/coaches who have full-time teaching loads provide one-on-one coaching to a substantial extent; 37 percent use teachers/coaches who do not have classroom teaching responsibilities. Fifty-six percent of schools have one-on-one mathematics coaching provided to a substantial extent by teachers/coaches who do not have classroom teaching responsibilities; 28 percent use teachers/coaches with full class loads to a substantial extent."

"*Teacher Induction Programs*. Formal induction programs provide critical support and guidance for beginning teachers and show promise for having a positive impact on teacher retention, instructional practices, and student achievement in schools. However, the effectiveness of these programs greatly depends on their length and the nature of the supports offered to teachers. Roughly 70 percent of schools across the grade bands offer formal teacher induction programs. About a third of schools have programs that last one year or less, and about a fourth of schools have programs that last two years."

"The research on effective induction programs for beginning teachers also suggests a number of supports that are important for a program's success. One key element

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is having an experienced mentor, in particular one who teaches the same subject or grade level as the mentee. Other important components of effective induction programs are ongoing communication with administrators, including an orientation meeting; offering common planning time with mentors or other new teachers; providing regular professional development opportunities; allowing new teachers to observe other colleagues, and to be observed; and giving release time and reduced teaching loads. Many schools at all grade levels have formal induction programs that include a number of these best practices. For example, the most predominant supports provided to beginning teachers include a meeting to orient them to school policies and practices (85–89 percent), formally assigned school-based mentors (81–85 percent), and professional development opportunities on teaching their subject (74–82 percent). In addition, 61–70 percent of schools give release time to observe other teachers in their grade/subject area. Schools at the elementary and middle grades level are more likely than schools at the high school level to offer common planning time with experienced teachers who teach the same subject or grade level (76, 68, and 52 percent, respectively). In contrast, high schools are more likely than their middle or elementary counterparts to provide release time for beginning teachers to attend national, state, or local conferences (51, 38, and 33 percent, respectively)."

"Given that mentoring plays an important role in effective induction programs, the percentage of schools that formally assign school-based mentor teachers was examined by different school characteristics. Urban schools are significantly less likely than their suburban or rural counterparts to assign mentors (78, 87, and 90 percent, respectively). School coordinators who indicated having formally assigned school-based mentors as part of the school induction program were asked to describe the schools' incentives and requirements of these mentors. About 90 percent of schools, when feasible, intentionally assign a school-based mentor who teaches the same subject or grade level as the beginning teacher. Also, roughly two-thirds of schools give school-based mentors training on effective mentoring practices, common planning time with their mentees when feasible, and extra compensation for their service. Still, only a quarter of schools intentionally give mentors release time or a reduced course load to work with their mentee."

<u>Chapter 4. "Science, Mathematics, and Computer Science Courses"</u>

"Time Spent in Elementary Science and Mathematics Instruction. Self-contained elementary teachers were asked how often they teach mathematics and/or science. Mathematics is taught in virtually all classes on most or all school days in both grades K–3 and 4–6. In contrast, science is taught less frequently, with only 17 percent of grades K–3 classes and 35 percent of grades 4–6 classes receiving science instruction all or most days, every week of the school year. Many elementary classes receive science instruction only a few days a week or during some weeks of the year."

"The survey also asked the approximate number of minutes typically spent teaching mathematics, science, social studies, and reading/language arts in self-contained classes. In 2018, grades K–3 self-contained classes spent an average of 89 minutes per day on reading instruction and 57 minutes on mathematics instruction, compared to only 18 minutes on science and 16 minutes on social studies instruction. The pattern in grades 4–6 is similar, with 82 minutes per day devoted to reading, 63 minutes to mathematics, 27 minutes to science, and 21 minutes to social studies instruction."

"*Science, Mathematics, and Computer Science Course Offerings*. Middle schools were asked whether they offer single-discipline courses (*e.g.*, life science, physical science), coordinated/integrated science courses, or both in each grade 6–8 contained in the school. Forty-five percent of schools containing sixth grade offer only coordinated/integrated science, and 35 percent offer only single-discipline courses; in grades 7 and 8, the percentage of schools offering only coordinated/integrated science is approximately the same as the those offering only single-discipline courses (about 40 percent). Fewer than one in five schools containing these grades offer both types of courses."

"Almost all high schools (97 percent) with grades 9–12 offer courses in biology/life science, with 70 percent offering non-college prep courses, 73 percent offering first year college preparatory courses, and 60 percent offering at least one second year biology/life science course. Overall, 94 percent of high schools offer some form of chemistry course. First-year college prep chemistry courses are offered in 72 percent and second year chemistry in 45 percent of high schools. Most high schools (82 percent) offer physics courses. Three-fifths offer first year physics, and two-fifths offer second year physics. Most high schools (84 percent) offer coursework in coordinated/integrated science (including physical science). Fewer high schools offer courses in environmental science (66 percent) or Earth/space science (59 percent) than in the other science disciplines. Only 27 percent offer a second course in environmental science; six percent of schools offer second year Earth/space science courses. Nearly one-half of high schools offer at least one engineering course; 31 percent offer non-college prep, and 29 percent offer first year college prep engineering courses. Only 17 percent of high schools offer a second year engineering course."

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"Biology is the most commonly offered AP course, available in about 4 in 10 high schools. About the same proportion offer some form of AP Physics, with AP Physics 1 being the most common type. AP Chemistry is offered in roughly one in three schools and AP Environmental Science in about one in four high schools. That the percentage of high school students with access to each course is much larger than the percentage of schools offering it indicates that larger schools are more likely than smaller schools to offer AP science courses. However, 27–80 percent of students do not have access to the various AP science courses. Not surprisingly, small schools tend to offer fewer AP science courses than large schools. On average, suburban and urban schools offer more AP science courses than rural schools. In addition, schools in the top two quartiles in terms of the percentage of students eligible for free/reduced-price lunch offer fewer AP science courses than schools with lower proportions of such students."

"The survey also asked if high schools offer International Baccalaureate (IB) courses. Very few schools offer the IB program and fewer than one in ten high school students have access to any of these science courses."

"The survey asked high schools about opportunities provided to students to take science and engineering courses not offered on-site. A small percentage of schools provide students with access to physics either by offering it in alternative years or by allowing students to take the course off campus. Over half of high schools have students take science and/or engineering courses at a college/university, and almost half provide access to concurrent credit/dual enrollment courses — courses that count for high school and college credit. About two in five high schools allow students to take science and/or engineering courses at a Career and Technical Education center or virtually through other schools/institutions. Fewer than one in five high schools have students take science/engineering courses at another high school or provide their own science and/or engineering courses virtually."

"*Other Characteristics of Science, Mathematics, and Computer Science Classes*. The 2018 *NSSME+* found that the average size of science and mathematics classes is generally around 21–24 students, whereas high school computer science classes tend to have around 17 students. However, these averages can obscure a wide variation in class sizes. For example, 15 percent of high school science and mathematics classes have 30 or more students."

"The distribution of female students and students from race/ethnicity groups historically underrepresented in STEM in elementary and middle school science and mathematics classes mirrors that of students in the nation, as students typically are required to take science and mathematics at each grade level. In high school, where students are generally not required to take each subject every year, the data show that historically underrepresented students are less likely to take science and mathematics classes. In high school computer science classes, only about a quarter of students are female or from a historically underrepresented race/ethnicity group."

"A pattern of decreasing enrollment of students from race/ethnicity groups historically underrepresented in STEM is seen in the class composition data across the progression of high school science courses. For example, students from these groups make up 43 percent of students in non-college prep science classes and 35 percent of students in first year biology classes, compared to only 27 percent in advanced science classes. In terms of gender, high school science courses tend to have classes that are evenly split between male and female students on average. Exceptions are non-college prep science classes and first year physics classes, which have smaller percentages of female students."

Chapter 5: "Instructional Decision Making, Objectives, and Activities"

"*Teachers' Perceptions of Their Decision-Making Autonomy*. Many in education believe that classroom teachers are in the best position to know their students' needs and interests and, therefore, should be the ones making decisions about tailoring instruction to a particular group of students. Teachers were asked the extent to which they had control over a number of curricular and instructional decisions for their classes. In science classes across all grade levels, teachers tend to perceive themselves as having strong control over pedagogical decisions such as determining the amount of homework to be assigned (59–74 percent), selecting teaching techniques (48–68 percent), and choosing criteria for grading student performance (41–59 percent). In contrast, especially in the elementary grades, teachers are less likely to feel strong control in determining course goals and objectives (17–36 percent); selecting textbooks/modules/programs (15–36 percent); and selecting content, topics, and skills to be taught (13–34 percent). In fact, in about a third of elementary classes, teachers report having no control over these decisions."

"*Instructional Objectives*. The survey provided a list of possible objectives of instruction and asked teachers how much emphasis each would receive in an entire course of a particular, randomly selected class. Understanding science concepts is the most frequently emphasized objective, although more so in secondary classes (about three-quarters of middle and high school classes) than in elementary (fewer than half of classes). Given the adoption

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in many states of the NGSS or NGSS-like standards, it is somewhat surprising that fewer than half of secondary classes, and only a quarter of elementary classes have a heavy emphasis on students learning how to do science. In addition, about a third of classes have a heavy emphasis on students learning science vocabulary and/or facts. Objectives least likely to be emphasized are learning about different fields of science and engineering and learning how to do engineering (ten percent or fewer science classes). In fact, 18–31 percent of science classes, depending on grade range, have no emphasis on learning how to do engineering."

"*Class Activities*. Depending on grade range, 42–48 percent of classes include the teacher explaining science ideas in all or almost all lessons. The majority of elementary science classes engage in whole-class discussions in nearly every lesson, though this activity becomes less frequent as the grade level increases. Approximately a third of K–12 science classes have students work in small groups in all or almost all science lessons."

"The survey also asked how often students in science classes are engaged in doing science as described in documents like *A Framework for K–12 Science Education* — *i.e*., the practices of science such as formulating scientific questions, designing and implementing investigations, developing models and explanations, and engaging in argumentation. Students often engage in aspects of science related to conducting investigations and analyzing data. For example, about half of middle and high school classes have students organize and represent data, make and support claims with evidence, conduct scientific investigations, and analyze data at least once a week. At the elementary level, about a third of classes engage students in these activities weekly. Across all grade bands, students tend to not be engaged very often in aspects of science related to evaluating the strengths/ limitations of evidence and the practice of argumentation. For example, fewer than a quarter of secondary science classes have students, at least once a week, pose questions about scientific arguments, evaluate the credibility of scientific information, identify strengths and limitations of a scientific model, evaluate the strengths and weaknesses of competing scientific explanations, determine what details about an investigation might persuade a targeted audience about a scientific claim, or construct a persuasive case. Even fewer elementary classes engage students in these activities weekly, and about a third never do so."

"Given recent trends to incorporate engineering and computer science into science education, the 2018 *NSSME+* asked teachers how frequently they do so. The typical science class experiences engineering a few times per year (48–51 percent of classes depending on grade level). About a third of science classes incorporate engineering at least monthly. In terms of coding, a large majority (71–89 percent) of classes never include coding as part of their science instruction. Interestingly, coding occurs somewhat more often in elementary classes than in middle or high school classes."

"*Homework and Assessment Practices.* Not surprisingly, the amount of time students are asked to spend on science and mathematics homework increases with grade range. For example, over half of high school mathematics classes are assigned one or more hours of homework per week, compared to under one-fifth of elementary classes. Homework expectations in high school computer science classes are similar to those in high school science classes."

Chapter 6. "Instructional Resources"

"*Use of Textbooks and Other Instructional Resources.* The 2018 *NSSME+* collected data on the use of various instructional resources, including commercially published textbooks or programs, both print and electronic. Of particular interest is how much latitude teachers have in selecting instructional resources. Instructional materials are designated by the district for most science and mathematics classes. The likelihood of having designated materials decreases from elementary school to high school in mathematics. Also, mathematics classes are generally more likely to have designated materials, perhaps due to the greater accountability emphasis in mathematics. High school computer science classes are very unlikely to have designated materials; only about a quarter have materials designated for them."

"Regardless of whether instructional materials had been designated for their class, teachers were asked how often instruction was based on various types of materials. Teacher-created units or lessons are very likely to be used on a weekly basis in science, and their prominence increases considerably with grade range, from 47 percent of elementary science classes to 86 percent of high school classes. In high school, after teacher-created lessons, commercially published textbooks and units or lessons from any other source are a distant second, with all the rest being relatively uncommon. In middle school science classes, the pattern is similar but less pronounced. In elementary science classes, fee-based websites and teacher-created units and lessons share roughly equal influence, followed by the textbook."

Teachers who responded that their most recent unit was based on their textbook were asked how they used it. Two important findings emerge from their responses. "First, when classes use commercially published and state/district-developed materials, the materials heavily influence instruction in all subjects at all grade ranges. Teachers in more than 70 percent of classes in the various

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subject and grade-level categories use the textbook substantially to guide the overall structure and content emphasis of their units. Second, it is clear that teachers modify their materials substantially when designing instruction. In roughly half or more of classes, teachers incorporate activities from other sources substantially, 'pick and choose' from the material, and modify activities from the materials."

"Teachers in roughly half of science, mathematics, and computer science classes skip activities in the material substantially. In all subjects, some of the most frequently selected reasons for skipping parts of the materials are: (1) having another activity that works better than the one skipped, (2) the science ideas addressed not being included in pacing guides or standards, (3) not having enough instructional time, and (4) the activities skipped being too difficult for the students. In more than 40 percent of classes, teachers skip activities that they deem unnecessary (students either already knew the ideas or could learn them without the activities). Differences across grades, however, are also apparent. For example, in mathematics, teachers in 38 percent of elementary classes cite the difficulty of the activity as the reason for skipping it, compared to 55 percent in high school mathematics classes. A similar pattern is evident in science. Also, not having materials for an activity is much more likely to be cited as a reason in science classes (54–62 percent) than in mathematics classes (24–27 percent) or high school computer science classes (28 percent)."

"Given that teachers often skip activities in their materials because they know of better ones, it is perhaps not surprising that teachers in well more than half of science, mathematics, and computer science classes supplement their materials. Of the reasons listed on the questionnaire, three stand out above the rest: (1) teachers having additional activities that they like, (2) providing students with additional practice, and (3) differentiating instruction for students at different achievement levels. The influence of standardized testing is also evident, with teachers in anywhere from about half to almost three-fourths of classes across subjects supplementing for test-preparation purposes. Finally, in 34–49 percent of classes, depending on subject and grade level, teachers supplement their published material because their pacing guide indicates that they should. This finding both speaks to the prevalence of pacing guides and suggests that supplementing is at least to some extent sanctioned or prescribed by schools and districts."

"When teachers reported that they modified their published material (which over half did), they rated each of several factors that may have contributed to their decision. Two factors stand out: teachers do not have enough time to implement the activities as designed (52–71 percent of classes), and the activities are too difficult for students (43–58 percent of classes). In science, teachers are also likely to cite not having the necessary materials or supplies for the original activities (53–62 percent of classes). Teachers are about equally likely to point to the structure of activities (either too much or too little) across subjects and grade ranges as the reason for modifications."

"*Facilities and Equipment*. Computer and Internet resources, including school-wide Wi-Fi and computers or tablets for students, are widespread. However, the amount of money schools spend on instructional resources more broadly seems quite inadequate, especially viewed as a per-pupil expenditure. In science, the problem is especially pronounced in elementary grades, where median per-pupil spending is considerably less than that spent in middle schools and especially in high schools. The lack of spending is likely related to the finding that elementary science teachers are less likely than their middle school and high school counterparts to view their resources as adequate."

<u>Chapter 7. "Factors Affecting Instruction"</u>

"*School Programs and Practices*. The designated school program representatives were given a list of programs and practices and asked to indicate whether each was being implemented in the school. These individuals were also asked about several instructional arrangements for students in elementary self-contained classrooms, such as whether they were pulled out for remediation or enrichment in science and mathematics and whether they received science and mathematics instruction from specialists instead of, or in addition to, their regular teacher. The use of elementary science specialists, either in place of, or in addition to, the regular classroom teacher, is uncommon (7–15 percent of schools). Pull-out science instruction, whether for remediation or enrichment, is also quite rare (8–10 percent of schools). The picture is quite different in elementary school mathematics instruction. Students are pulled out for mathematics remediation in more than 60 percent of schools, and in just over one-third of schools, students are pulled out for mathematics enrichment. The prevalence of these practices may be due in part to the fact that mathematics is much more likely than science to be tested for accountability purposes. In addition, Title 1 funds are more likely to be targeted for remediation in mathematics and reading than in science."

"The study asked high schools about the prevalence of several possible course policies, specifically, block scheduling, single courses resulting in credit for multiple subjects, and allowing engineering courses to count toward students' science graduation requirement. The rationale for block scheduling is largely two-fold. First, the schedule affords longer class periods, which can be espe-

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Clearinghouse Update

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

Converting the Oak Ridge Gaseous Diffusion Site to an Industrial Park

Harmer Johnson described his tour of the Nevada Nuclear Test Site in our Winter 1990 issue, and the Editor described his tour of the site at Hanford (WA), which produced the plutonium-239 which fissioned in the nuclear bombs tested at Alamogordo (NM) and dropped over Nagasaki. The bomb dropped over Hiroshima fissioned uranium-235, which was largely produced by the process of gaseous diffusion in some of the largest buildings in the world at Oak Ridge (TN) – they had to be large because the process was so inefficient, compared with the centrifuges now used for isotope separation.

Eventually five such buildings – known as K-25, K-27, K-29, K-31, and K-33 – plus ancillary structures occupied the Oak Ridge site. The 14 October 2020 issue of *World Nuclear News* described the demolition of these buildings and decontamination of the site to make way for the East Tennessee Technology Park, which now houses 20 businesses. The pictures on page 17 highlight where the former buildings stood and what the site looks like today.

Sweden's Repository for "Spent" Nuclear Fuel

The sequence of unfulfilled plans to store the "spent" nuclear fuel removed from reactors in the United States has been chronicled throughout the issues of this *Newsletter*. The 14 October 2020 issue of *World Nuclear News* reported that the municipal council of Östhammar approved the building of a repository at Forsmark in Sweden. Readers of this *Newsletter* can recall that Goldstein and Qvist's *A Bright Future* report that Sweden has made a concerted commitment to nuclear-generated electricity to minimize carbon dioxide emissions. Building this repository will facilitate keeping that commitment.

Inoculation *vs.* Vaccination

The report in our Winter/Spring 2020 issue from a 4 July 2019 *Trenton Times* story on George Washington having his troops inoculated against smallpox failed to distinguish between inoculation and vaccination, as has been pointed out by another story from the 18 December *Trenton Times*. The more recent story cites two authoritative best-sellers – Ibram X. Kendi's *Stamped from the Beginning: The Definitive History of Racist Ideas in America* and Isabel Wilkerson's *Caste: The Origins of our Discontents* – in relating that the practice of inoculation, in which the pus of a smallpox victim is inserted into a cut in the skin to induce a mild case, yet grant immunity, originated in Africa and was taught to American whites by their slaves. An article on the NIH (National Institutes of Health) website <ncbi.nlm.nih.gov/pmc/articles/PMC1200696/> traces inoculation (also called variolation) to China and India as well as Africa, but it was not introduced to the West until the early 18th century, whereas Edward Jenner did not develop the process of vaccination, using matter from cowpox lesions, until the end of that century.

Sweden's Commitment to Nuclear Energy Questioned

Sweden's commitment to nuclear-generated electricity to minimize carbon dioxide emissions cited above has been called into question by Sama Bilbao y Léon, director general, and John Lindberg, public affairs manager, of the World Nuclear Association. According to the 26 February 2021 issue of *World Nuclear News*, they wrote the following in an article:

> After years of punitive taxation and political wrangling, four nuclear reactors have been subjected to unnecessary and politically motivated closures in less than five years - and we are now seeing the effects. With the retirement of Ringhals 1 and the arrival of what used to be a normal Swedish winter, the country's electricity system is coming away at the seams. The southern regions, which previously housed six more reactors, are now forced to import fossil-based electricity. . . .

Domestic Mo-99 Source Approved

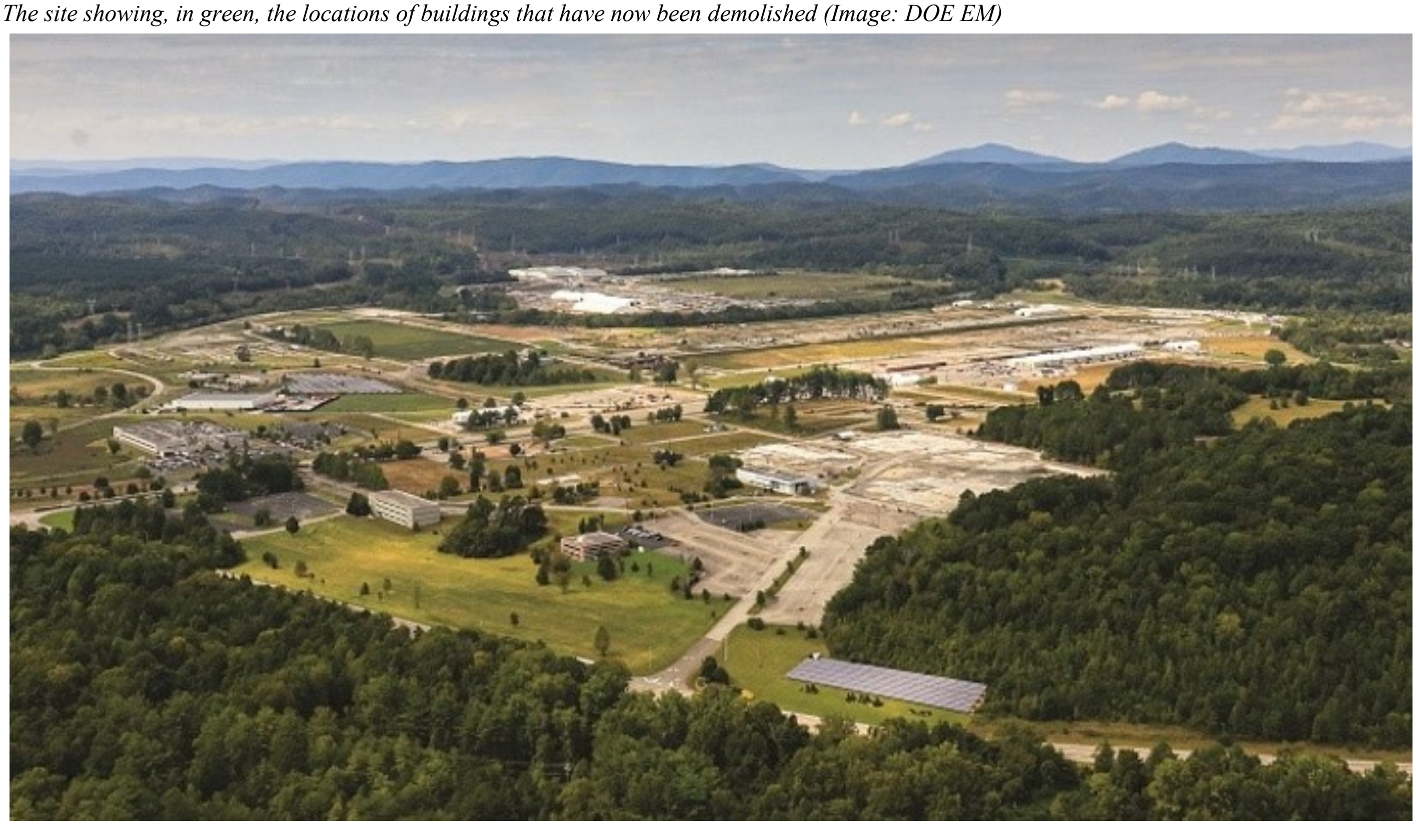
According to the 9 January 2021 issue of *World Nuclear News*, "the US Food and Drug Administration (FDA) has approved NorthStar Medical Radioisotopes, LLC's process to produce molybdenum-99 (Mo-99) from concentrated Mo-98 and related software upgrades for its RadioGenix System technetium-99m (Tc-99m) generator. This will significantly increase US production and capacity for non-uranium based Mo-99."

The focus of
our Spring 2021
issue
will be

"The Phasing Out of Fossil Fuels"

Watch for it!

The site showing, in green, the locations of buildings that have now been demolished (Image: DOE EM)



The Oak Ridge site as it looks today (Image: DOE EM)

RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Alison L. Hill, "The Math Behind Epidemics," *Phys. Today*, **73**(11). 28-34 (Nov 20).

In this time of the COVID-19 pandemic, *Physics Today* has enlisted the services of an assistant professor in the Institute for Computational Medicine at Johns Hopkins University to address the mathematical modeling of epidemics. Hill begins with R_0, "the average number of new cases . . . caused by a typical infected individual." It depends, she continues, on "three factors: the contact rate, . . . the transmissibility, . . . and the infection duration." The first can be reduced by social distancing, the second by wearing masks, and the third by therapies that are not available for COVID-19.

Hill points out that R_0 is difficult to estimate. But if the growth rate r, derived from the doubling time at the onset of the epidemic, the latent period T_E (time between infection and the onset of infectiousness), and the infectious period T_I can be determined, then R_0 can be calculated. Unfortunately, for COVID-19 the latent period is shorter than the incubation period, when symptoms arise. Thus a person becomes infectious with COVID-19 before the onset of symptoms.

Hill also points out what R_0 doesn't tell us: a disease's virulence, and "the time scale over which a disease spreads." Regarding the former, she also discusses the case fatality risk (CFR) and the infection fatality risk (IFR).

2. Daniel Helsing, "James Jeans and the Mysterious Universe," *Phys. Today*, **73**(11). 36-42 (Nov 20).

Ninety years ago James Jeans wrote *The Mysterious Universe*, in which he both described for popular audiences the then known structure of the universe and raised his own philosophical speculation about its consequences for humanity. The latter has been regarded as been regarded as going beyond the bounds of science, a practice that has been shunned by subsequent writers about science for the general public.

3. Brian F. G. Katz, Damian Murphy, and Angelo Farina, "Exploring Cultural Heritage Through Acoustic Digital Reconstructions," *Phys. Today*, **73**(12), 32-37 (Dec 20).

By "simulating the acoustics of destroyed or altered amphitheaters, cathedrals, and other architectural sites," "auralization . . . the sound equivalent of visualization . . . provides historians, musicologists, and others with a perspective not available using more established research methods" for "exploring cultural heritage through acoustic digital reconstruction."

4. Lindsey Kirkland and Kristen Poppleton, "Climate change education: A model of justice-oriented STEM education," *Connected Science Learning,* **3** (1), Jan-Feb 21). (https://www.nsta.org/connected-science-learning-january-february-2021/climate-change-education-model-justice-oriented)

"Integrating science and social justice in the classroom can be difficult," these authors state, but they continue by citing climate change is a good topic with which to do it. This is because of the disproportionate impact that climate change has had on Black, Indigenous, and People of Color (BIPOC).

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

27-19 June 2021. ISTE21 – online and in San Antonio.

21-24 June 2021. PBL World 2021 – online project based learning workshops. Visit info@pblworks.org.

18-22 July 2021. NEED National Energy Conference for Educators (in-person), Albuquerque, NM. Visit <nationalenergyconference.org>.

18-21 July 2021. World Multiconference on Systemics, Cybernetics, and Informatics (WMSCI21) in Orlando, FL, presently accepting only virtual participation <http://www.iris-2021conf.org/wmsci> and <http://www.iris-2021/cfp-summer2021.asp>.

REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Lee Smolin, *Einstein's Unfinished Revolution: The Search for What Lies Beyond the Quantum* (Penguin, New York, 2019). ISBN 978-0-14-31116-0.

Roberto Mangabeira Unger and Lee Smolin, *The Singular Universe and The Reality of Time: an essay in natural philosophy* (Cambridge, Cambridge, 2015). ISBN 978-1-107-07406-4.

What does it take to write an essay? Time. And what does it take to write a book report? A book to report on. As I was almost finished reading *Einstein's Unfinished Revolution: The Search for What Lies Beyond the Quantum* by Lee Smolin I was gifted an unread advance reading copy of the companion book *The Singular Universe and The Reality of Time: and essay in natural philosophy* by Roberto Mangabeira Unger and Lee Smolin. In *Einstein's Unfinished Revolution* Smolin repeatedly refers in the text and in extensive footnotes to ideas more extensively developed in *The Singular Universe.* And so, after reading both these books, the philosophy book being over 500 pages, and with time to utilize in fruitful endeavor, as these books are full of ideas I am most interested in, I gladly endeavor to write briefly a report as to what and why both these books held me in rapt attention.

One of the most confusing of the many mysteries of the quantum theory is how entangled particles when actually measured a distance apart result in correlated outcomes; an unexpected result Einstein called "spooky action at a distance." What happens to make that occur? How can Schrodinger's cat be thought to be both alive and dead locked inside a closed box and then found to be alive or dead when the box is opened? Quantum decoherence violates the rules of relativity and locality; and defies rational logic and basic physical sense, as Einstein knew. Einstein observed that the Copenhagen interpretation was an incomplete description of nature and believed that quantum physics relied on hidden variables to be as it is. After reading the Smolin book I believe Einstein was correct. It will take many years of experiments and evidence to see this new thinking to a conclusion but the basic sense of it is clear. I always found it difficult to accept some of the conclusions of modern quantum theory. And all my studies never revealed to me these more developed basic issues discussed in this book, as if there were a censorship of reason and rational understanding at the university. All of the misdirection is due to the Born rule in quantum theory that squared probabilities result in measurables. How can actual events be brought forth from randomized equations? Quantum theory as it is constituted today is not deterministic. However, Smolin encourages us to distinguish probable events with low chance of occurring from actual measurable, "be-able" events that do occur. In a sense this book presents ideas that were always known by Bohm and De Broglie, and presciently explained by Leibnitz. One's need to accept that the universe, as Hugh Everett postulates, that has any decoherence event causes the universe to bifurcate and split into possible alternatives each and every time any quantum measurement occurs. This splitting occurs when the collapse of the wave function happens to any two entangled particles, when decoherence occurs; this is called anti-reality by Smolin. He explains why it seems so absurd. He makes it clear he holds to the more physically rational and logically believable ideas of the Bohm-De Broglie pilot wave theory. Smolin calls this critical realism and develops a quantum theory in which all our knowledge is relational, not absolute. He asserts time as a fundamental aspect of the physical universe and space as an emergent feature of the singular universe. This is where the second book becomes most helpful.

I first set out to read *The Singular Universe and the Reality of Time* in an incomplete fashion, with multiple starts on specific topics and isolated readings from the main text. I was looking to bolster the footnotes and references in *Unfinished Revolution*. But as it was an additional discussion based on the fundamental reality of time and the impossibility of many universes that dovetailed with *Unfinished Revolution*, I began it to add to the interesting ideas in *Unfinished Revolution* even though it was a thick philosophical book. I was correct to do so. The basic good sense *The Singular Universe* offers to bolster *Unfinished Revolution* is that since we are within all there is, the space and time universe of general relativity, we are unable to assume an outside knowledge of time; and an outside knowledge of space. Whenever discussing any modern ideas about the physical universe as is known (Gamow's *One, Two, Three, Infinity* comes to mind) with others, the profound inability to NOT be enabled to step outside space or time was a real obstacle. Leibnitz also saw this failure of thinking as did Descartes. How can we view the Universe from only inside that Universe? Using logic much like Gödel, who showed math as being valid only within itself, we are trapped within the physical universe and are wrong to assume an outside position to view all space and all time. With that assertion, an obvious fact, Unger and Smolin underpin their thoughts with the implicit observation that time is real, a physical part of the universe and space emergent, evolving as we know. This helps *Unfinished Revolution* embrace the realism of a quantum theory with evidence of the useful value of time, as a plan and a process. Relational events in space and causal events in time makes more sense to me than random and non-deterministic

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quantum situations. Discussing thermodynamics and information theory as two differing ways time can be viewed, Unger and Smolin connect the dots where a reason and a plan are more how time can be realized in a real universe than just a random unfolding of chance events. And with space part of the evolution of the expanding universe it makes, as Leibnitz suggested, better sense than the absolute space of Newton. These two books taken together discuss much more than what is wrong with quantum theory and how to understand time as real. If these ideas interest you, reading Smolin and Unger will offer much to think about.

\- Jack DePalma

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

Max Tegmark, *LIFE 3.0: Being Human in the Age of Artificial Intelligence* (Knopf, New York, 2017). 364 pp. ISBN 978-1101946596. $14.90.

Noted astrophysicist Max Tegmark has written an excellent book on AI, *LIFE 3.0*. He begins the book with a fictitious story describing the development and introduction of an AI (artificial intelligence) system identified as Prometheus. In the story, Tegmark writes of the process used by Prometheus to establish a world government "amplified by an intelligence so vast that it could potentially enable life to flourish for billions of years on earth and throughout our cosmos." After concluding the story, he writes "Could something like (this) actually occur, and, if so, would you want it to?"

The title of the first chapter, "Welcome to the Most Important Conversation of Our Time," sets the tone for the book. The book is about AI, but Tegmark expands it to include AGI – *Artificial General Intelligence* - which he identifies as being able to accomplish any goal. He goes on to describe meeting Google cofounder Larry Page, writing, "(Page) might go down in history as the most influential human ever to have lived: my guess is that if super-intelligent life engulfs our universe in my lifetime, it will be because of Larry's decisions." Page believes that letting digital minds be free will result in "good outcomes."

Tegmark writes of organizing an AI conference held in January 2015, titled "The Future of AI: Opportunities and Challenges." The conference produced a consensus from all who attended ("A remarkable group of more than fifty researchers in AI and related fields"), described in a letter signed by over eight thousand people (see futureoflife.org/ai-open-letter/). The letter includes the statement, "Our AI systems must do what we want them to do." Near the end of the chapter Tegmark has a good diagram, Figure 1.6, identified by the label, "Which AI questions are interesting depends on how advanced AI gets and which branch our future takes."

In the second chapter there is an interesting graph (Figure 2.8) labeled "How many computations per second can you buy for $1,000?" Included is information about neural networks, described as dominating the field of machine learning. Each chapter ends with a summary labeled "The Bottom Line." In the summary for chapter 2 Tegmark writes "If AI progress continues, then long before AI reaches human level for all skills, it will give us fascinating opportunities and challenges involving such issues as (computer) bugs, laws, weapons and jobs."

In the next chapter Tegmark describes current breakthroughs, some of which are described as "HS (Holy S—t) moments." An example involves the author's experience with language translation. Tegmark speaks nine languages, including Russian, French, and Mandarin, and wrote, "There are almost no languages left that I can translate between better than the AI system developed by the Google Brain team. He suggests that you try it at <https://translate.google.com>.

The human process of learning from making mistakes is examined in terms of risks versus benefits. This leads to information about AI-safety research, and examines it as applied to space exploration. The author writes of a space launch mishap that resulted in a loss of hundreds of millions of dollars, and says, "AI may help us explore other solar systems – if it's bug free." He goes on to describe beneficial AI applications in finance, manufacturing, transportation, energy, healthcare, communication, the judicial process, and employment. There is also a section on AI weapons systems, which includes having humans "in the loop." The summary items listed at the end of the chapter that this reviewer considers most important are that our laws need updating to keep up with AI and career advice for kids: go into professions that machines are bad at."

In the chapter titled "Intelligence Explosion?" Tegmark writes about the potential for good and bad AI outcomes. He indicates that he believes the best question is, "What should happen, what future do we want?" He also writes, "If we don't know what we want we are unlikely to get it."

In the fifth chapter the author identifies the importance of taking the long view. "Aftermath: The Next 10,000 Years" includes two quotes at the beginning: "I, for one, welcome our new computer overlords," said by Ken Jennings, upon his *Jeopardy!* loss to IBM's Watson, and "Humans will become as irrelevant as cockroaches," attributed to Marshall Brain. Seven questions about the reader's personal preferences are listed, as well as after-

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math scenarios, and nine "Sector Systems," identifying human lifestyle preferences. The next chapter looks farther into the future, as in "The Next Billion Years and Beyond."

Chapter seven examines the importance of setting goals in terms of biology, psychology, and the Golden Rule. There is also an analysis of Isaac Asimov's *Three Laws of Robotics*, and a long analysis of the nature of consciousness, an important topic to deal with when considering the creation of systems beyond the intelligence of humans. In a section titled "Meaning" Tegmark writes, "It's not the universe giving meaning to conscious beings, but conscious beings giving meaning to our universe."

The epilog to the book opens with a quotation from author Isaac Asimov, "The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom." It includes information about a conference held in January 2017, at Asilomar, in Pacific Grove, California. This conference results in The Asilomar Principles, which cover three aspects of AI: Research Issues, Ethics and Values, and Longer Term issues.

It took me more than two years to address writing this review, as reading the book made me anxious and apprehensive about AI. Everyone who values the future of humanity will find this book interesting and informative. It would make good required reading for all students on the verge of high school graduation, as they will live with Artificial Intelligence in some form.

- Frank Lock

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

Gino Segrè and Bettina Hoerlin, *The Pope of Physics*: *Enrico Fermi and the Birth of the Atomic Age* (Holt, New York, 2016). xi + 351 pp. ISBN 978-1-62779-005-5, $30.00

David N. Schwartz, *The Last Man Who Knew Everything*: *The Life and Times of Enrico Fermi, Father of the Nuclear Age* (Basic, New York, 2017). xxiii + 451 pp. ISBN 978-0-465-0-7290-7. $35.00.

Surprised as I was to find Thomas Young characterized by Andrew Robinson as "the last man who knew everything" in reviewing his book of that title in our Fall 2009 issue, I was even more surprised almost ten years later by yet another book with the same title. After my curiosity revealed that the subject of this second book about a supposedly omniscient person was Enrico Fermi, I reflected with some understanding that he alone among noteworthy physicists has made contributions to both theory and experiment. But my awareness of those contributions was considerably broadened by reading these biographies.

Both authors are related to Nobel laureates in physics. Segrè (whose wife is Hoerlin) is the nephew of Emilio Segrè (1959), Schwartz is the son of Melvin Schwartz (1988). Segrè is a physics professor. Schwartz a political scientist, who explains in his preface how reading a paper in 2013 by Valentine Telegdi about Fermi among his late father's papers made him want to learn more about Fermi. Seeing that the most recent biography had been written in 1970 by Emilio Segrè motivated him to write his own biography as a way not only to learn more about Fermi but also to enhance others' awareness of Fermi's achievements.

Curiously, by the time Schwartz completed his biography of Fermi there *was* a more recent one available, that by Segrè and Hoerlin. As I began to read Segrè and Hoerlin's biography, I was reminded how my high school English teacher, Col. C. R. Stribling, had taught me how Shakespeare began his plays *in medias res*, for this is how Segrè and Hoerlin begin their biography: not with Fermi's birth or ancestors, but on 16 August 1945, the day of the text explosion of the first nuclear bomb, code-named Trinity. Their description of what Fermi did that day – release scraps of paper when the shock wave hit so that he could determine the yield of the bomb by pacing to find how far the scraps had scattered – says more than anything else what made Fermi Fermi.

The other critical day in Fermi's life was 2 December 1942, the day that Fermi demonstrated the first sustained fission chain reaction, which showed the feasibility of both the bomb based on fission of Uranium-235 that was dropped on Hiroshima and the production of Plutonium-239 that was used in the bomb dropped on Nagasaki. I noted that Schwartz particularly rose to dramatic heights in describing how Fermi's understanding of neutron physics allowed him to control not only the reaction but how he presented it to his audience.

Both biographies cover the major events of Fermi's life – how his abilities were recognized at an early age and mentored by his father's friend Adolfo Amidei before he went to college and by Senator Orso Mario Corbino after; his bombardment of the elements with neutrons, recently discovered by James Chadwick, to ascertain what new radioactivities could be generated, but mistaking what was nuclear fission for generation of transuranic elements from the neutron bombardment of uranium; his marriage to Laura Capon and their "escape" to the U.S. via Stockholm after he received the Nobel Prize in physics in 1938; and his work on the Manhattan Project.

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Most of this I had already known. But there was much more to learn: why Fermi-Dirac statistics and the Fermi level for electron energies in solids bear his name, from his application of the Exclusion Principle to statistical mechanics way back in 1925; and his great facility in both the research lab and the lecture hall, which especially showed forth in his postwar years at the University of Chicago before his untimely death in 1954 at age 53.

Because Schwartz's biography is longer than that of Segrè and Hoerlin, it expectedly provides more detail. But it is interesting to see where that additional detail is found. The number of pages Schwartz devotes to Fermi's life before he came to live permanently in the U.S. in 1938 is only 20 percent more than those devoted by Segrè and Hoerlin; and the difference in coverage of Fermi's life in America through the end of World War II is even less. But Schwartz devotes approximately twice the number of pages to Fermi's life in Chicago after World War II as Segrè and Hoerlin do. Schwartz goes into more detail about Fermi's interactions with students and professors, including extended quotations. Some of these come from interviews he conducted, including one from his student Geoffrey Chew, who gave him the title of his book, which was also echoed by Ugo Amaldi.

In analyzing Fermi's life and career, even wondering why Fermi, given his unique broad view and facility across all the subdisciplines of physics, was not the one to solve the divergence problem of quantum electrodynamics after developing his theory of weak interactions as early as 1933 or to have the insight that finally came to Stanislaw Ulam and Edward Teller to overcome the final barrier to the development of thermonuclear weapons, Schwartz concedes that

> Obviously, he did not know everything. His knowledge of science beyond physics was superficial, and his knowledge of history, literature, art, music, and much else besides was limited, to say the least. He was not a universal genius. (p. 365)

But, Schwartz continues,

> Fermi was certainly the last man who knew everything about physics. . . . He knew everything about how the physical world worked across subdisciplines and across theory and experiment as far as physicists were able to know these things during his lifetime. . . . We may never see another like him. (p. 366)

Segrè and Hoerlin have a special reason for the title of their book, too. When Fermi and his students (Franco Rasetti, Emilio Segrè, and Edoardo Amaldi, known as "the Boys") set up their lab their lab in a villa at 89A Via Panisperna that established Rome as an early center of experimental nuclear physics, they assumed what Segrè and Hoerlin call "ecclesiastical monikers," (p. 68) and Fermi's was "Il Papa."

Here are two biographies of a man known for his dedication to physics and his inspiration to all in his profession. They are both delightful to read and add honor to a man who has already been honored by having his name attached to both a chemical element and a national laboratory, among other things. Although they overlap each other considerably in their coverage, each contains information not found in the other. You might want to do as I did: read them both.

\- John L. Roeder

Debora L. Spar, *Work Mate Marry Love: How Machines Shape Our Human Destiny* (Farrar, Straus and Giroux, New York, 2020). 367 pp. $28.00. ISBN 978-0-374-20003-9.

Richard Rhodes's *Energy* (reviewed in our Winter/Spring 2019 issue) tells the story of humanity in terms of its forms of energy. Simon Winchester's *The Precisionists* (reviewed in the same issue) tells the story of humanity in terms of its manufacturing processes. Debora Spar does the same in terms of technology. But she does more. Spar doesn't limit herself to the past. She also portrays the present and even ventures into possibilities for the future. And while Winchester provides no notes, Spar provides 56 pages of them.

After a Prologue which gives the reader a taste of what is to follow comes the first part of the book, "The Way We Lived," consisting of three chapters. The technology of the first of these chapters is the plow, which enabled agriculture. Prior to the advent of agriculture humans lived in nomadic bands, she tells us, by virtue of their necessity for survival. Agriculture gave humans the "ability to *control* nature's bounty, rather than just searching for it . . . the first major step that humans took toward technological mastery" – "between 9500 and 8500 B.C." "It also made us settle down." (p. 22) Because man's greater strength was needed to use a plow, agriculture made women more dependent on men.

Agriculture made children less costly (not needed to be carried over nomadic wanderings) and more useful (to tend fields). In fact, so useful were they for agriculture that reproduction became important for women. Because men wanted to be able to identify their children, monogamous marriage became increasingly important. Spar writes of "coupling of sex, property, and progeny." (p. 26) Formal marriage customs began around 3500 B.C., and polygamy was allowed for men. As agriculture brought greater control of women, the gender of societal gods shifted from female to male. Some settlements succeeded to the point of developing culture beyond agriculture, and their rulers were typically authoritarian. Au-

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thoritarian rulers could also control their people through their water sources.

Although new inventions like the stirrup, loom, and windmill appeared toward the end of the Middle Ages, agricultural technology remained the same, and this dictated continued dependence on monogamous marriage as a cornerstone of society. There was also the ascent of the church – Catholicism in Europe, Islam in the Middle East – to support this societal structure. But during the time the world in which people died was essentially the same as the one into which they were born.

The technology of the second chapter describing "The Way We Lived" is steam, which gave rise to the modern industrial state whose cities attracted men and their families to be paid for the work they did there. Thomas Newcomen's steam engine enabled water to be pumped from coal mines, but James Watt improved its efficiency and enabled it to generate rotary motion. This enabled steam-powered transportation and, in conjunction with cotton imported from the New World at the expense of millions of enslaved Africans, the British textile industry, the world's first mass industry.

In no longer earning their living directly from their work, people lost autonomy. They were now paid to work for bosses on a schedule set by the bosses and at the pace of the technology the bosses gave them to use. Since women could not meet the needs of both factory and home, they were consigned to the home while their husbands were consigned to the factory. Although women (particularly young and unmarried) and children staffed early mills in the textile industry, subsequent technology that demanded greater strength subsequently made factory jobs the province of men. Moreover, mechanization of agriculture reduced the need for men to work on farms. In fact, their need for employment in factories caused men to protest when their bosses sought to replace them with lower-paid women, and nineteenth century legislation reduced the hours women were allowed to work. Thus was enabled to nineteenth century nuclear family, headed by a man and woman working full-time jobs, his at the factory, hers in the home, taking care of it and the providing of creature comforts for the family (though some women, whose husbands were not as well-salaried, might hire out part-time to women with wealthier husbands).

The technological advance of the Industrial Revolution made life better for some, worse for others. And it did so with a far greater rate of change than had occurred in eight thousand years of agricultural dominance.

The third chapter describing "The Way We Lived" is devoted to three technological developments of the first half of the twentieth century: automobiles (which gave women and young people added mobility), home appliances (which reduced the drudgery of unpaid housework), and contraceptives (which gave women control over their sexual and reproductive lives). Henry Ford's Model T made the automobile available to the masses. Although men considered manipulating an automobile to be too complex for women, "by the later 1930s, women in the United States were driving as frequently as men." (p. 71) Providing increased mobility, the auto gave rise to suburban sprawl and turned stay-at-home women into family chauffeurs. It also extended increased mobility and opportunity for sexual expression to teens, who saw getting their driver's license as a rite of passage into adulthood.

Two electrical appliances that were especially significant in reducing housework drudgery for women were the refrigerator and the washing machine (the Thor in 1907, the fully automatic Bendix in 1927). These and other "white goods" enabled feminism and the entry of large numbers of women in the work force (37% of the U.S. work force in 1970).

"If cars gave women the means to escape their homes, and appliances gave them the time to do so, it was birth control that freed them at last from their most enduring form of labor: conceiving, birthing, and caring for babies," writes Spar (pp. 81-82) – it separated "sex from reproduction, pleasure from pregnancy." (p. 82) A subject limited to intimate conversation, birth control was historically unscientific. Charles Goodyear's 1839 success in preventing "rubber from cracking in cold temperatures or melting in warm ones" (p. 84) enabled the condom, and inverting the combination of estrogen and progesterone that made women fertile led to development of "the pill," approved by the FDA in 1957 for "gynecological disorders." (p. 86) But unlike the previous technologies of the plow and steam, which changed the means of *production*, birth control technology changed the means of *reproduction*.

Spar continues with this theme in the first of her three chapters on "The Way We Live Now." While some technologies can *prevent* pregnancy, others have enabled new ways to produce it, she observes. Since these new technologies can produce babies without a nuclear family, they portend new possibilities for family structures. Artificial insemination compensates for an infertile male, and *in vitro* fertilization for an infertile female, with the embryo able to be analyzed and corrected for single gene diseases. Although they were developed to circumvent infertility and heterosexual couples, now combinations of surrogates and donated eggs and sperm allow any "family" to have a baby.

Increased numbers of births outside wedlock (from 38.4/1000 in 1938 to 49.6/1000 in 1958 in the U.S.)

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brought about court cases and legislation based on the best interests of the children. The same principle applied to children of heterosexual couples employing surrogates and ascribed parental rights and responsibilities to who planned the child's birth. This was subsequently extended to same-sex couples, of which only one could be a biological parent – and this in turn paved the way to same -sex marriage.

All alternative means of reproduction discussed by Spar thus far are based on an egg fertilized by a sperm. *In vitro gametosis* (IVG) goes beyond this by creating gametes from stem cells *in vitro* (although this has been achieved thus far only in mice). After pairs of such gametes are matched to form an embryo, a cell from that embryo can be used to form additional gametes, to create additional embryos, in a sequence in which each embryo represents the equivalent of a compressed generation in a world of natural heterosexual reproduction. In this way IVG can produce offspring with more than two parents – and those parents can be any combination of genders, except that there must be a least one male parent to produce a male child in order to provide the Y-chromosome.

Spar marvels that the Jetsons of the 1960s had all sorts of advanced technologies but lived in a society in which reproduction was the same as then. Sixty years later we have not acquired the technologies of the Jestons' everyday life but our methods of reproduction have seen much technological advance.

The separation of sex from reproduction occasioned by contraception is the basis for the second chapter in "The Way We Live Now." In her chapter on "Sex and Love Online" Spar observes that a meaningful relationship requires 1) *information* about who is available and 2) expressing a *preference* among the possibilities. As time as progressed, the number of those available and the freedom of people to make their own choice have increased. The Internet has vastly increased the information about available people. Spar probed Match.com, which algorithmically makes matches based on data submitted, and Tinder, which provides pictorial information of who is available but lets users express their own preference by swiping. Some consequences of this are that (1) the larger number of choices has made making a choice more difficult (two people on a date will scan their cell phones in cases something "better" comes up), (2) "beautiful" people benefit disproportionately, while others have been rejected and feel resentment that has led to violence, (3) the age of marriage is increasing and the fertility of women is decreasing (currently 1.87 in the U.S.), and (4) the percentage of interracial marriage has increased (from 10.7% in 2000 to 17% in 2015 in the U.S.).

Based upon John Maynard Keynes's prediction that breadwinning men would be replaced by machines and thus deprived of the jobs which have defined them since the Industrial Revolution, Spar's third chapter on "The Way We Live Now" takes a completely different tack. Just as technology in the home (plus contraception) *allowed* women to imagine new roles for themselves, technology in factories is *forcing* the reimagining of new roles for men, especially the white men who are most affected. "Marx or Lenin would see this as the oppression of the proletariat by the forces of monopoly capitalism," Spar writes (p. 163). While this meant fewer jobs in fields that have employed mostly men, jobs have opened up in fields and employing mostly women. In fact, the recession of 2008-2009 saw huge increases in male employment but hardly any change in female unemployment, Spar notes. This also necessitated reconfiguring gender roles in families.

The increased options for women were enabled by technology but were also driven by feminists and "women's studies" at universities, and they didn't affect men who didn't do housework or get pregnant. "Men haven't changed yet because they haven't had to," Spar observes (p. 170) While some men have found employment among the new realities, others, particularly the least educated, have turned to means of escapism: "In the digital age, jobs based on brawn will increasingly fall prey to those based on brain, or in information technologies." (p. 173) Although "men haven't found their postindustrial prophet yet," she continues, (p. 177) "their lives will resemble those of contemporary women more than contemporary man." The apostles of the monolithic masculinity of the Industrial Revolution "are far more likely to blame immigrants, or women, or politicians, or Wall Street," (p. 176), she concludes, but the villain that did them in was technology.

The first of Spar's three chapters on "The Way We Will Live" is on changes in gender as well as sexual expression. Just as some people are not attracted sexually to the opposite gender, there are people who do not identify with the gender that corresponds to the genitalia of their bodies: "Sexual orientation is who you go to bed *with*. Gender identity is who you go to bed *as*." (Dr. Norman Spack, Boston Children's Hospital, p. 187). The first surgery and knowledge of hormones determining sexual characteristics which today enable people's bodies to be aligned with their gender identities dates back to a century ago, and a Dutch protocol can delay puberty hormonally to allow the transition to be less arduous. Combining this with what she wrote in chapter 4 about technological advances in reproduction, Spar notes that we are "replacing the ancient dichotomy of male and female, man and wife, with something far more fluid" (p. 206) and "the whole biological calculus that drives humans with one array of chromosomes to pair with the other becomes vestigial, old fashioned." (p. 207)

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REVIEWS

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The second chapter on "The Way We Will Live" deals with human interaction with and attraction to objects that they have made to replicate living things. But so far, Spar observes, none of these has had a brain that can link "conscious thought with physical action" (p. 216) – *i.e.*, think. We have programmed computers, she continues, to defeat humans in complex games, and some see this as a first step toward elevating AI (artificial intelligence) to the point of besting humans and taking over the planet – but this would require computers to evolve further, and to do so *one their own*.

When Spar observes that AI in the service of humanity would take the form of robots doing our jobs (an extension of chapter 6) but then asks what would *we* do, I found myself wondering whether they could run society without human supervision. She also notes that robots can also provide companionship to humans – as dolls with the possibility for providing for sexual needs or as pets to provide comfort to the elderly, something Sherry Turkle wrote about in *Alone Together*, reviewed in our Fall 2011 issue. In fact, Spar cites Turkle's work on p. 234. "As humans were are clearly biologically programmed to fight and to work," she writes (p. 236), and some of our robots are being programmed in these ways. "But we are also and more fundamentally programmed to love," she rejoins, and we have created robots to which we have become attached.

In her third chapter on "The Way We Will Live" Spar takes on what might be regarded as the ultimate in technological achievement, "Engineering the End of Death." One way she considers this is a digital re-creation from uploading "a lifetime's worth of memories, reflections, and thoughts" (p. 240) to a robotic head and adding a prosthetic body, something already imagined by Michio Kaku in *The Future of the Mind* (reviewed in our Fall 2015 issue). It occurred to me that mapping the content of what is stored in a brain onto a computer might be fraught with difficulty, since the brain is not organized like a computer, and Spar herself raises the question, "can even the smartest of smart machines really *think*?" (p. 262) Another type of digital re-creation could be made from imaging cross-sectional slices of the brain with an ion beam electron microscope, much as a CAT scan is made.

Another approach that Spar considers in the quest for immortality is delaying the process of aging. One way to do this is preventing the shortening of telomeres when our cells divide – something mice do by producing telomerase, but Spar cautions that "infinitely replicating cells are by their very nature cancerous" (p. 249). Compounds that show promise in lengthening life include sirtuins, proteins that slow the metabolic rate by shutting down sections of an organism's genome, and metformin, which lowers blood sugar in type 2 diabetics and might slow the progression of heart disease and cancer.

One reason to fear death is to fear that the decedent will not be remembered, but living forever would enable us to be in continuous contact with loved ones and always live in their memory. Spar wonders how this would affect our choice of marriage, but it occurred to me that it would remove the need for marriage and reproduction – but also deprive humanity of the progress that could come from further ideas from future generations left to be unborn. Spar also recognizes that the fear of not being remembered is without warrant, because each of us has the opportunity to leave behind a record of what we have done, and today's social media are taking care of this automatically.

In her "Conclusions," subtitled "Welcome to Tomorrowland," Spar briefly discusses how technology will affect the four areas named in her book's title. Referring to what she has already written in chapter 6, she observes that the pattern of long-term employment to do designated physical labor during established times ushered in by the Industrial Revolution is being replaced by machines doing most jobs, with humans working increasingly in a gig economy. Most of these gigs can be done in whatever space and time the worker chooses, using digital technology – the same used the rest of the time for entertainment. A challenge is to enable humans to feel that they are leading rewarding lives in this type of situation.

In her concluding comments on mating, Spar reiterates how contraception has decoupled sex from reproduction and restates what she has written about new possibilities for reproduction in chapter 4 and sex in chapter 5, noting the plethora of combinations that might be more than some really want. At a time that there are more interracial and interethnic marriages (to both homo- and heterosexual couples), the actual marriage rate has basically halved between 1960 and 2016 in the U.S., Japan, and Western Europe, and it's no longer needed to procreate humanity. And with so many interactions that can merit our intensive feelings, the opportunities for love to be expressed will only increase.

Throughout this book Spar has characterized humans as tool builders, and she views human evolution in terms of the tools we build and use. It is not realistic to ban them, except for nuclear weapons, she says, although Mary Shelly noted in 1818 that nothing "is so painful to the human mind as great and sudden change." (p. 288) But Spar is concerned about the inequities that result from new technologies' tendency to favor the wealthy. She has already articulated what she expects these technologies to be in writing her book. We need to "create a framework through which a society can adapt to technological change, instead of simply being trampled by it." (p. 285)

\- John L. Roeder

AI not a good predictor of social behavior

Like everything else since March 2020, the winter "Science on Saturday" lectures at the Princeton Plasma Physics Laboratory moved online in winter 2021. On 16 January 2021 the lecturer was Arvind Narayanan, Associate Professor of Computer Science at Princeton University. He spoke on "How to recognize AI snake oil."

Narayanan opened by stressing the importance that scientists understand pseudoscience, especially for being able to debunk its false claims. Although AI (artificial intelligence) has achieved many successes, such as defeating humans at such complex games as GO, it is an umbrella term for related technologies, and this has allowed the term AI to be applied to many areas of everyday life, in a way that has misled the public. One example is algorithmic hiring, which Narayanan said is growing fast, because it is held to be non-discriminatory (and also lucrative for the companies purveying it). He showed a screenshot from a 30-second video to be evaluated as a job interview.

Narayanan displayed a list of five areas in which AI *has* made genuine rapid technological progress:

1. Content identification (Shazam to identify songs, and reverse image searches)
2. Face recognition (much improved over the years, due to improved data bases)
3. Medical diagnoses from scans
4. Speech to text
5. Deep fakes.

He noted that these are all problems relying on perception. The ethical concerns about these applications arise from their power because of their *high* accuracy.

He then went on to a list of areas in which AI is "far from perfect" but improving:

1. Spam detection
2. Detection of copyrighted material
3. Automated essay grading
4. Hate speech detection
5. Content recommendation ("if you like this, you'll like . . . .").

Narayanan said that these are all examples of *automating judgment* (but for which there is no "right answer"), in which errors could be made – which caused him to add the question of what recourse is available if an error *is* made.

He followed this with a category he called "fundamentally dubious":

1. Predicting criminal recividism
2. Predicting job performance
3. Predictive policing
4. Predicting terrorist risk
5. Predicting at-risk kids.

These are all examples, Narayanan said, of *predicting social outcomes*. Their use is based on public belief that this is possible, and ethical concerns are amplified by *inaccuracy*.

But can social outcomes be predicted? Narayanan asked. To shed light on answering his rhetorical question, he cited the Fragile Families & Child Wellbeing Study, in which Matthew Salzanik, Ian Lundburg, Alex Kindel, Sara McLanahan and 45 other researchers monitored the success of 12942 children from 4242 families the past 20 years. The children were visited every two years and administered a survey. The goal of the study was to predict six outcomes at age 15 based on surveys through the age of nine for half the children based on what was actually known to have happened to the other half. An algorithm using 13000 features was used to predict whether the family endured material hardship, the student's GPA, grit, whether the family was evicted, whether the family received job training, and whether parents were laid off. The correlation coefficients comparing predicted and actual outcomes ranged from a high of 0.23 for the first outcome to a low of 0.03 for the last – "barely better than random" (for which the correlation coefficient would be zero), Narayanan said. But the "kicker," he added, was that a simple linear formula based on four variables did almost as well.

For another example he cited the COMPAS algorithm, with 137 features, to predict recividism, used to decide release on bail. Its accuracy is only 65±1%, only slightly better than random (50%), and it yields twice as many false positives for black defendants as white defendants. Here, too, a simpler "logistic regression" (with two features, age and number of "priors") predicted with 67±2% accuracy.

Based upon occurrences such as these, Narayanan concluded that bias in machine learning is the rule, not the exception. Machine learning, he explained, discovers patterns in existing data and reproduces them to classify new inputs. This is because the existing data reflect human society and thereby capture biases, stereotypes, and historical prejudices. So if we base our algorithms on data from the past, we're going to predict a future that is like the past.

In the two cases Narayanan cited, a simpler formula worked almost as well as the algorithm. If this is the case, he asked, why not use the simpler formula? He then went on to note an example in which we actually do this, in the case of the system of awarding points toward suspension of a driver's license for traffic violations.

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Horizon Survey

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cially important in science, where a 50-minute class constrains the kinds of laboratory activities that can be conducted. Second, students can take eight classes per year instead of six or seven. One main downside of block scheduling is that there is less total instructional time available for each class. One-third of all high schools use block scheduling. Additionally, one in five high schools allow students to earn credits in multiple subjects with a single course, perhaps because of the increasing prominence of STEM initiatives in schools. Finally, 21 percent of the schools that offer engineering courses allow these courses to count toward students' graduation requirement for science."

"The study also asked if high schools allow students to demonstrate mastery of course content without the normal seat time requirement by, for example, taking a test or performing a task. About a quarter of all high schools allow for this in mathematics and science, while 10 percent of schools allow students to demonstrate computer science mastery for credit."

"High school program representatives were asked how many years of science, mathematics, and computer science students are required to take in order to graduate. The vast majority of high schools require at least three years of science and mathematics; more than half require four years of mathematics. For most schools, graduation requirements are just as demanding as state university entrance requirements. However, when there is a difference, graduation requirements tend to be more rigorous; 40 percent of high schools require more science and 32 percent require more mathematics courses for graduation than state universities do for entrance."

"In contrast, nearly three-quarters of schools do not require any computer science in order to graduate; almost all that do require one year or less. Additionally, program representatives were asked if computer science counts toward graduation requirements in any other subjects. Only a small percentage of high schools allow computer science to count toward graduation requirements in mathematics, science, or foreign language."

"*Extent of Influence of State Standards.* It is clear that state standards have a major influence at the school level. For example, 79 percent or more of program representatives agree that teachers in the school teach to science and mathematics standards. Similarly, a large majority of representatives agree that science and mathematics standards have been thoroughly discussed by teachers in the school and that there is a school-wide effort to align instruction to standards. Both practices are especially prevalent in mathematics, with 83–90 percent of representatives agreeing across the grade levels. It is somewhat surprising that only about half of high schools are in districts that organize professional development based on science and mathematics standards."

"*Factors That Promote and Inhibit Instruction*. Overall, the climate for mathematics instruction is generally seen as more supportive than that for science. For example, in 78 percent of schools, the importance that the school places on mathematics is seen as supporting instruction, compared to only 51 percent of schools for science. Lack of time and materials for science instruction, especially in the elementary grades, is particularly problematic. Programs to support students in computer science are relatively uncommon, with only 26 percent of high schools requiring any amount of computer science for graduation and fewer than one-third of all schools offering programs or practices to enhance interest in computer science beyond encouraging students to participate in camps."

Two years after publication of the 2018 *NSSME+* one of its authors, P. Sean Smith, wrote a subsequent report, *Trends in U.S. Science Education from 2012 to 2018*, using the same format, to report the differences between the 2012 and 2018 reports. It can be accessed online at <http://www.horizon-research.com/2018-nsmme-science-trends-report.> The 2018 *NSSME+* can be accessed online at <http://horizon-research.com/NSSME/wpcontent/uploads/2020/04/Report_of_the_2018_NSSME.pdf>.

Artificial Intelligence

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Narayanan concluded with a list of harms inflicted by AI in predicting social outcomes:

1. Hunger for personal data
2. Massive transfer of power from domain experts and workers to unaccountable tech companies
3. Lack of explainability (job applicants evaluated by algorithm can't know why they are denied)
4. Distracts from interventions
5. Veneer of accuracy
6. Risk of bias

Then he listed his takeaways:

AI excels at some tasks but can't predict social outcomes.

We must resist the enormous commercial interests that aim to obfuscate this fact.

In most cases, manual scoring rules are just as accurate, far more transparent, and worth considering.

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Engineering Ed and STS

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7. Study how the brain works to make better artificial intelligence.
8. Secure cyberspace and fight cyber warfare.
9. Provide energy from fusion.
10. Repair and improve urban infrastructure (roads, water treatment, bridges).
11. Make solar energy less expensive.
12. Advance health data to improve medical treatments.
13. Manage the impact of forming and industry on the nitrogen cycle and the environment.
14. Manage carbon emissions to protect the environment.

Three activities are presented in the article, one asking students to brainstorm tasks in their daily lives that could be made easier by technology and comparing the list of brainstormed tasks with the grand challenges, another on making solar energy economical, and a third on how civil engineers approach urban infrastructure. As I read through these activities, I couldn't help but be struck by how each of the fourteen grand challenges could be the topic of an educational module produced by a 21st century version of the New York Science, Technology, and Society Education Project (NYSTEP), for which I developed and presented such educational modules as a Resource Agent in the late 1980s and early 1990s. This similarity can be noted in the diagram below which illustrated the pedagogical flow of a NYSTEP module.