Penn Engineering

ENGINEERING A GREEN WORLD

UNIVERSITY OF PENNSYLVANIA | SPRING 2019

Active Learning

Chris Callison-Burch, associate professor in Computer and Information Science, leads his students in CIS 530, Computational Linguistics, in the Forman Active Learning Classroom. In this course, students approach the problem of how computers can understand and produce natural language text and speech. Students study algorithms like vector space models of semantics and build machine translation models and dialog systems.

Callison-Burch's own work helps computers connect words with their counterparts in other languages, especially when direct translations aren't obvious. Recently, he's incorporated images as definition-matching go-betweens, something that can be displayed on the screens on every wall of the classroom.

CONTENT

Penn Engineering / Spring 2019

University of Pennsylvania
School of Engineering and Applied Science

> "THERE ARE STRENGTHS AT PENN THAT ALLOW US TO BUILD MULTIDISCIPLINARY AND MULTI-INSTITUTIONAL PARTNERSHIPS THAT ARE ONLY POSSIBLE BECAUSE OF PENN'S ECOSYSTEM."

Penn Engineering Magazine
alumni@seas.upenn.edu
215-898-6564
www.seas.upenn.edu

Vijay Kumar
Nemirovsky Family Dean

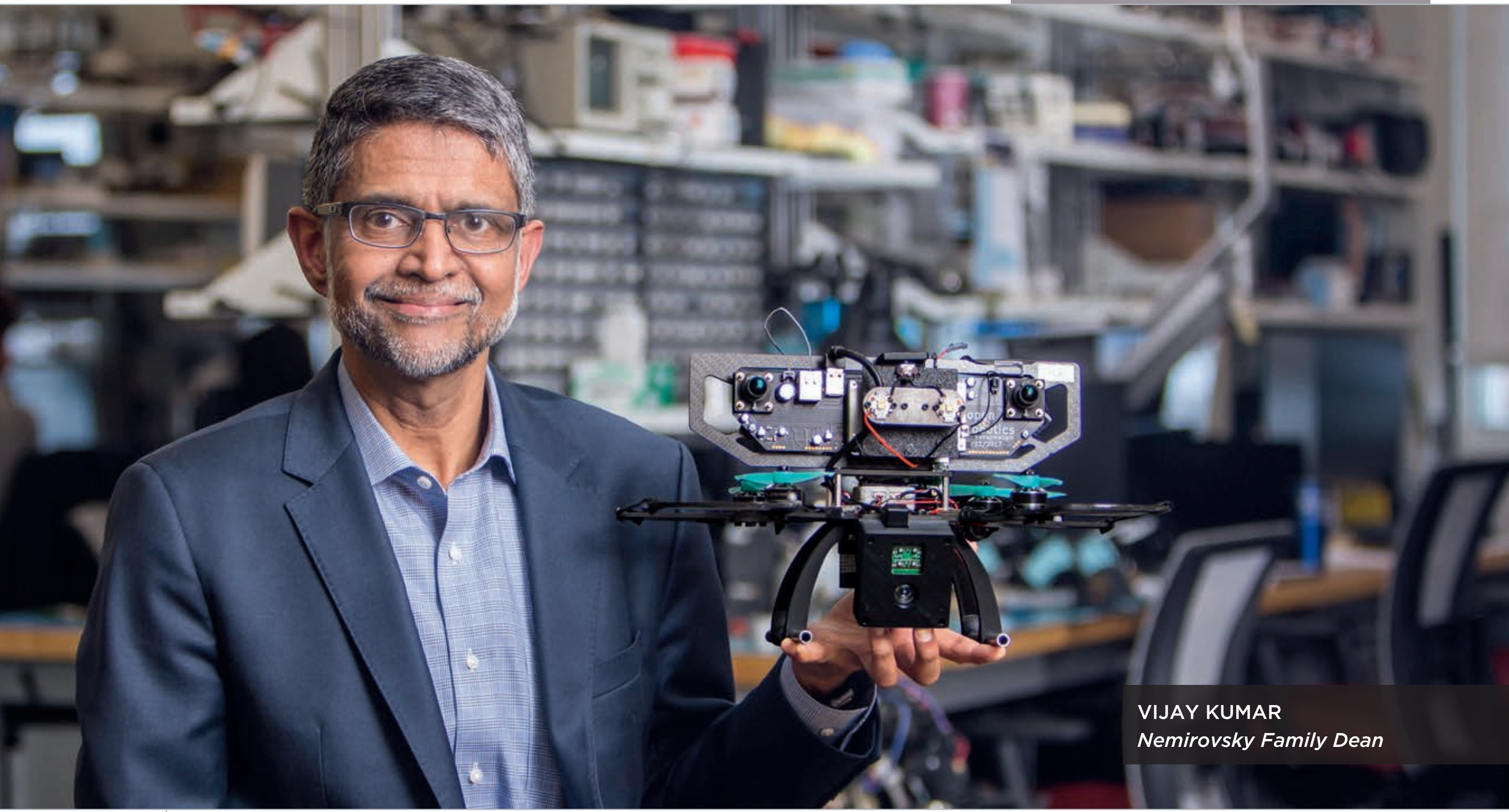
George W. Hain III
Vice Dean, External Affairs
Development and Alumni Relations

Joan S. Gocke
Director of Communications
Editor

Olivia J. McMahon
Associate Editor

Design
Kelsh Wilson Design

Photography
Kelsh Wilson Design
Felice Macera



VIJAY KUMAR
Nemirovsky Family Dean

Fridays at PERCH

I have been the dean at Penn Engineering for nearly 4 years. As one can imagine, at first I was continually astonished by the range and weight of the responsibilities that a dean addresses. I continue to embrace these challenges and celebrate the tremendous achievements of the School, which occur in no small part due to the talented teams of students, faculty and staff whose passion, enthusiasm and leadership I count on every day. I travel the world, interacting with our strong communities of alumni and friends. I get to see firsthand the impact that our School has on a global scale.

From the moment I arrived on campus 30 years ago, I've had an active research career and have mentored hundreds of students. When I became dean, I was determined that my time in the office would include maintaining a strong commitment to these "first loves."

So, while I spend almost every hour of every day "dean-ing," I spend Fridays at the Pennovation Center's third-floor Penn Engineering Research and Collaboration Hub, what we lovingly call PERCH. Under the leadership of Dan Koditschek, Alfred Fitler Moore Professor in Electrical and Systems Engineering, this space has grown into a vibrant, collaborative R&D environment, designed to promote fundamental research and accelerate the lab-to-market technology transfer pipeline in robotics, internet of things and embedded systems tech.

In the weekly shedding of my jacket and tie for my Superman-to-Clark-Kent metamorphosis, I find joy not only in being just another guy in the lab, but also in that I keep in step with what is going on in the School on a fundamental level. I'm not just reading a report or email filtered through the lens of a proud PI, I am able to witness what is really occurring—both in success, and yes, failure.

It would be easy to forget that a dean is at their core an engineer, a teacher, a researcher. Students who matriculate during the tenure of a single dean may not even know their research discipline! By staying in the trenches, I have found that my time as dean has not only allowed me to feel personal satisfaction that my research and teaching continue to thrive, but also that I am a more effective leader and ambassador for the School.

It's a Small World

A CONVERSATION WITH DANIELLE BASSETT AND DUNCAN WATTS

In July, Duncan Watts will join Penn Engineering as the University's 23rd Penn Integrates Knowledge Professor. As such, Watts will have primary appointments in the Department of Computer and Information Science in Penn Engineering, as well as in The Wharton School and the Annenberg School of Communications. His research reflects the value of these kinds of interdisciplinary connections; he is one of the progenitors of the field of network science, which studies how unique members of dynamic systems interact to influence the behavior of the whole.

Watts sat down with Danielle Bassett, Eduardo D. Glandt Faculty Fellow and Associate Professor in the Departments of Bioengineering and in Electrical and Systems Engineering in Penn Engineering. Bassett's own work on network science draws from the worlds of physics, electrical engineering, applied math and neuroscience, as well as Watts' theories.

The two discussed their intertwining academic networks and how combining basic and applied science contributes to the culture of innovation at Penn. An excerpt of their conversation follows.

Danielle Bassett (DB): I came into the field about a decade after you, so I was influenced by your work. But even in the mid-2000s, the term "network science" was not used that frequently. What was it like when you were getting your start?

Duncan Watts (DW): Network science definitely didn't exist when I started doing network science.

There were little pockets of other disciplines, like with graph theory in mathematics, and sociology and anthropology with social network analysis. But there wasn't any field that thought about the network as an organizing principle across different areas of applications.

That, to me, is what network science is—this idea that lots of problems of interest across many disciplines can be viewed through the lens of a network. You have some collection of entities that are connected to one another, and the structure of that network could have important consequences for the behavior of the whole system.

That was the idea that Steven Strogatz [Jacob Gould Schurman Professor of Applied Mathematics at Cornell University] and I were working from—this notion that you should be thinking about the structure of the network to understand the dynamics of the system—in our paper, "Collective Dynamics of Small World Networks" in 1998. But it wasn't actually called network science until several years later.

DB: As it happens, my first paper was called "Small-world Brain Networks," and I finally have a paper coming out with Strogatz as a coauthor, so now you and I are separated only by two steps in the worldwide co-authorship network.

That notion of "small worldness" was very important and has continued to be very important for a really long time. For many physical systems, like a crystal structure for example, we can sort of blur our eyes and say that, even though there are lots and lots of atoms, they roughly interact with each other in the same way.

But with small-world networks, we're increasingly realizing there are many systems where that kind of assumption is completely false. It requires that we understand the underlying architecture of these interactions in order for us to see how the system will behave.

DW: When we first started tackling this problem, we were thinking about a biological question—the synchronization of crickets—from a mathematical modeling perspective. The realization that I had at the time was exactly what you just said. All of the models used this "mean field assumption" where everything is interacting with the average of everything else. And that seemed completely false in the context of crickets sitting in trees chirping at each other.

DANIELLE BASSETT
Eduardo D. Glandt Faculty Fellow and Associate Professor
Bioengineering

DUNCAN WATTS
Stevens University Professor
Computer and Information Science

So I was mulling over what would be a framework for describing the actual system. And I recalled a conversation I had with my father about a year earlier when he casually mentioned that you're only ever six handshakes away from the president of the United States. I hadn't heard that at the time, but later I learned that this was a topic that had come up over the years in sociology, called the small-world problem—also known as six degrees of separation.

DB: I'm also very curious about how small teams can come up with very unusual and creative ideas, and which group of people is best at doing that. It's hard to predict the way people interact that allows that to happen.

DW: Well, that's a good question, and I think it's relevant to academia. A couple of years ago I wrote a paper about what I called solution-oriented social science. If you pick any kind of nontrivial problem in social science, psychologists will have written about it and sociologists will have written about it and political scientists will have written about it. You end up with 5 or 50 perspectives that are so different from one another that you cannot figure out how they all fit together.

After a while it occurred to me that this was really a consequence of the way that academic research is organized. We are all trained within a particular discipline, and our individual toolboxes produce such different ways of thinking that it's not even as simple as deciding which one's answers are right or wrong. They're not even necessarily comparable.

I think the myth that we have about the academic publishing system is that it somehow sorts this problem out. That everybody publishes their papers and then we all read each other's papers and then, over time, knowledge will accumulate. And I think actually that doesn't really happen very much, and it especially doesn't happen across disciplines.

The approach I'm interested in, and this is somewhat inspired from having worked in an industry lab for the last decade or so, is that rather than starting with a theory and asking, "What does my theory have to say about problem x?", you ask, "What is the theory we need to build in order to solve this problem?"

DB: It struck me that the goal that you're outlining is actually very similar to the way science was done 2,000 years ago. These ancient philosophers were looking at the world and saying, "Oh, that's interesting, I wonder why…" And they were doing a lot of characterization, but were also building theory from observations of a real system. It made me wonder whether we've digressed by siloing the disciplines and training students to have a narrow view of what science is.

DW: You can go back to the ancients, but a lot of this specialization has really happened in the last hundred years.

One of the turning points was a very influential memo written by Vannevar Bush, who was the director of the Office of Scientific Research and Development under Franklin Roosevelt and the godfather of the National Science Foundation. He described this model of science as moving in a linear path from basic to applied science. Bush felt very strongly that the two shouldn't mix, but this was always a bit of a myth—it didn't really come from anywhere except Bush's impression of how things should work.

DB: I've been talking to my department chair about developing a broad course that asks students to think carefully about those questions—the definition of science, its history and its goals. What would you put on the syllabus?

DW: About 20-odd years ago, there was a really nice book written by Donald Stokes called "Pasteur's Quadrant." He pointed out that what Bush had described was incomplete; at minimum, you should think of science along two axes. One axis would be to what extent it is advancing basic understanding and on the other axis should be whether it is related to some sort of application.

You have traditional basic science, which is curiosity-driven and has no obvious application, in Bohr's quadrant, which is in reference to Niels Bohr's theory of the atom. And then you have applied science, which is about trying things until they work and not interested in advancing basic understanding, in Edison's quadrant. But then there was Pasteur's quadrant, where it's both things at the same time. You are solving an applied problem, but you are also advancing basic understanding at the same time.

And by the way, Ben Franklin, when he wrote the mission statement of the University of Pennsylvania, specifically stated that the purpose of a university was not just to develop basic knowledge but also to solve applied problems. Penn is really a good place to be doing this.

By Evan Lerner

Aleksandra Vojvodic

LEVERAGING CHEMISTRY FOR A GREEN WORLD

Many of the technologies that could facilitate a sustainable future already exist. The idea for a hydrogen fuel cell, a technology that produces electricity without carbon emissions, has been around for over 100 years. The cost and lifetime of fuel cells, however, have prevented them from becoming ubiquitous. To complicate things further, fuel cells are only as green as the production of their hydrogen fuel. That means that renewable hydrogen sources such as water-splitting need to become economical enough to replace production from natural gas.

Fortunately, these challenges all have something in common. At their core they are chemistry problems, and each can be tackled by taking things to the atomic level. “All these systems—electrocatalysis, batteries, fuel cells—they all have something happening at the atomic scale. Protons, electrons and ions are moving around. It’s not only energy being transferred; there’s a process going on that is chemical in nature,” says Aleksandra Vojvodic, Skirkanich Assistant Professor of Innovation in Chemical and Biomolecular Engineering.

Vojvodic uses quantum mechanics to model the chemical reactions happening in these technologies as opposed to performing the reactions in a laboratory. By solving equations that describe chemical systems, Vojvodic is able to work on crucial energy and environmental issues in a completely virtual way.

STORING ENERGY

In theory, reusable batteries can store and dispense energy again and again, saving the energy and materials it would take to make more. But in reality, batteries degrade over time. Vojvodic is collaborating on two different projects to address a mysterious cause of this degradation. The collaborations were formed via the Scialog program, which brings together multidisciplinary teams of researchers who have never worked together before to undertake scientific challenges.

With one group, Vojvodic is studying batteries with liquid electrolytes, such as the lithium-ion battery you might find in your cell phone or an electric vehicle. The other team is focused on solid-state batteries: heavier, stationary energy storage. Both projects are focusing on the electrolyte-cathode interface, where a layer of an unidentified material forms over time.

BY SOLVING EQUATIONS THAT DESCRIBE CHEMICAL SYSTEMS, ALEKSANDRA VOJVODIC IS ABLE TO WORK ON CRUCIAL ENERGY AND ENVIRONMENTAL ISSUES IN A COMPLETELY VIRTUAL WAY.

“Nobody knows what it is,” Vojvodic says, “and it’s very hard to see what’s happening there. Our experimental collaborators can see only the before and after. But we can model it. We can run and solve these quantum mechanical equations that let us study the interaction molecule by molecule.” With the combined effort of her lab’s theory work and her experimental collaborators, Vojvodic is working out the chemical mechanism that forms this layer and is developing ways to stabilize the problem.

The work on solid-state batteries is familiar territory, Vojvodic says, as she studied solid-state physics as an undergraduate. Her later work as a staff scientist at the SLAC National Accelerator Laboratory at Stanford University developed her expertise in solid-liquid interfaces.

Despite her physics background, Vojvodic was never tempted to go into fields like astronomy or high-energy physics. “I wanted to be more rooted on this planet. Being aware of climate issues has always been one of my interests.”

Contour plots, like the one behind Aleksandra Vojvodic, Skirkanich Assistant Professor of Innovation in Chemical and Biomolecular Engineering, help researchers pinpoint where the right mix of properties will intersect in a synthetic material.

Aleksandra Vojvodic brainstorms potential new strategies for materials design, taking inspiration from fundamental electronics structure chemistry concepts. Pictured with doctoral students (from left) Luke Johnson, Abhinav Raman and Anthony Curto.

CATALYZING SUSTAINABILITY

In combating climate issues, Vojvodic is up against long-standing infrastructure such as gasoline-powered engines and utilities that run on natural gas. Hydrogen fuel provides an alternative, but hopes for a "hydrogen economy" largely hinge on developing efficient and sustainable sources of hydrogen.

One method is to split water into its hydrogen and oxygen components using electricity; a "green" process if the electricity comes from a renewable source. Catalysts can make this process more efficient by lowering the amount of energy the reactions require and speeding up the reactions. Catalysts are not consumed in a reaction and can be used again and again. Vojvodic and her students are developing catalysts for both the hydrogen- and oxygen-forming parts of the reaction. An efficient water-splitting method could also benefit the production of ammonia, a compound made of nitrogen and hydrogen, as this process currently sources most of its hydrogen from natural gas.

ALEKSANDRA VOJVODIC HAS DEVELOPED A PROTOCOL THAT HELPS NEW LAB MEMBERS GET STARTED IN THE COMPUTATIONAL ASPECTS OF THE WORK.

Ammonia production also accounts for about 2 percent of the world's energy use—in other words, just over the same amount of energy as all buses, trains, and two- and three-passenger vehicles worldwide combined. It is a key ingredient in the fertilizers that help our crops grow and is a precursor to many industrial chemicals, so while we might not stop making it, Vojvodic thinks we can find a better method.

The process uses so much energy partly because it requires high temperatures and pressure. Many plants, however, are pros at fixating nitrogen under tamer conditions, using enzymes in their roots. One of Vojvodic's projects seeks a way to imitate plants' methods in order to make ammonia at a lower energy cost.

Ideally, all of these endeavors could come together in a chain of environmentally friendly links. "If we can get electricity by collecting sunlight, and use that electricity to split water and make hydrogen, then we can combine that hydrogen with nitrogen to make ammonia fertilizers to grow our crops," Vojvodic says.

But she realizes that solutions are never as simple as they seem. Platinum, for instance, is a common catalyst in fuel cells but is a relatively rare element. Cobalt is more abundant but its mining is laden with issues of health, safety and child labor. "You can solve one problem, but in reality, things are more complex than that," Vojvodic says. "There are always multiple factors. How earth-abundant is your material, how cheap, how efficient, and what is its lifetime? All of these have to come into your equation, and there are trade-offs."

MODELING SOLUTIONS

How, then, to solve such a complicated equation of needs? Armed with the tools of her physics background and the power of supercomputers, Vojvodic uses quantum mechanics to model and test thousands of materials faster than she could in a chemistry lab. This lets Vojvodic do "virtual experiments" on materials' viability as catalysts, and build up fundamental knowledge of structure-reactivity relationships.

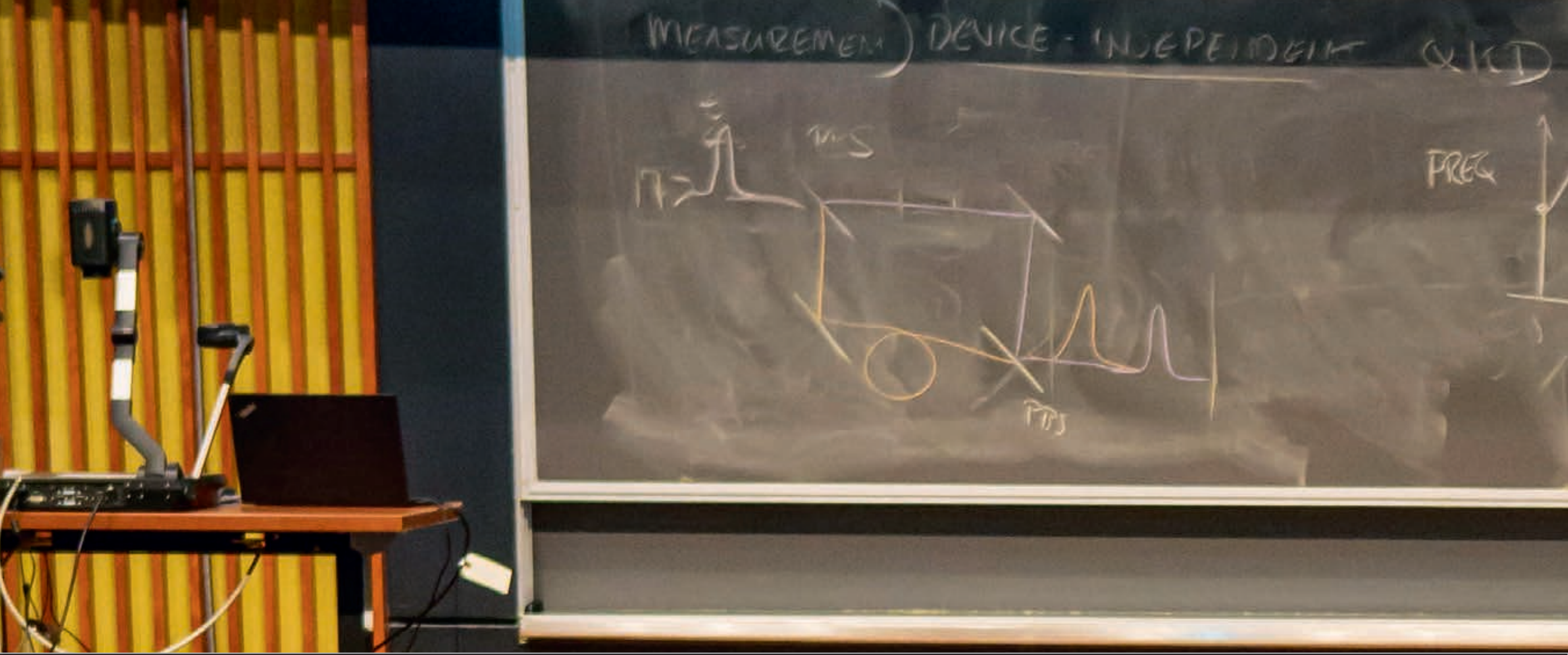
"We do a lot of calculations, then collect the data and look for patterns," Vojvodic says. "If you have a few thousand of these computational observations, you can start to make some conclusions about what makes a material work."

Vojvodic has developed a protocol that helps new lab members get started in the computational aspects of the work. For the classroom, she developed a new course, Computational Science of Energy and Chemical Transformations, to teach graduate and advanced undergraduate students the same skills. The curriculum teaches concepts behind atomic-scale modeling and allows students to try it hands-on, using an educational allotment of Vojvodic's NSF supercomputer time. The class culminates in a final project in which students work on a real-world problem in catalysis or energy.

Vojvodic looks forward to expanding her work to encompass even more of these fundamental issues. One area of interest is green chemistry, a field devoted to finding new chemical methods that use and produce less hazardous material and result in less waste, both in labs and on an industrial scale. Vojvodic is also interested in clean-water chemistry: finding ways to filter heavy metals and organic compounds from water sources.

"That's what drew me to computational, atomic-scale work," Vojvodic says. "There are many problems that you can work on, because everything is about the chemistry and physics of the materials."

By Lida Tunesi



The Perfect Storm

LEE BASSETT'S QUANTUM RESEARCH IS MAKING WAVES

Lee Bassett can usually be found in his Quantum Engineering Laboratory at Penn Engineering, or enjoying time with his family and occasionally playing the tuba or piano in local music groups. But when a perfect storm produces large waves at the Jersey Shore, Bassett and lab member David Hopper head to the coast to surf.

"Waves carry energy, but we don't talk about physics while we're in the water," Hopper says. "We shut it off and have fun, but the connection is there. Quantum physics is basically wave mechanics with complex numbers."

The laws of quantum physics govern the submicroscopic world within individual atoms; revolutionary new kinds of computing, sensing and communication are being built around the laws' unusual properties. For example, the quantum-mechanical model postulates that electron behavior can be mathematically understood by treating electrons as waves of matter, rather than particles. Quantum technologies need to measure and manipulate the quantum states of these waves, but the physical conditions required are extremely difficult to produce, requiring a protected-yet-accessible microscopic environment in which individual quantum states can be initialized, made to interact, and measured. Most quantum systems rely on ultra-cold temperatures and high vacuums to remain stable, limiting them to highly controlled laboratory settings.

Bassett's team recently discovered a new quantum system in a two-dimensional material, which functions at room temperature and can be coupled to other devices. While exploring defects in hexagonal boron nitride (h-BN), a one-atom thick semiconductor material, the researchers observed an optical effect where individual electrons respond to an applied magnetic field. That effect depends on the electrons' spin, which is a quantum-mechanical property that can be used to define a quantum bit, or qubit, the building block of quantum technologies.

"The balance between isolating and controlling a quantum system is a constant trade-off," says Bassett, assistant professor in the Department of Electrical and Systems Engineering. "Quantum systems need to preserve quantum properties for a significant amount of time, which means they need to be isolated. At the same time, we need to control and interact with the system. That's the challenge, and spin states have proven to be a good solution."

Because h-BN doesn't require extreme conditions or expensive equipment to keep its qubits stable, this discovery opens up an array of possible quantum technologies.

Bassett led the study along with Annemarie Exarhos, who was a post-doc in his lab and who now holds a faculty position at Lafayette College. Lab members David Hopper and Raj Patel also contributed to the study, as did Marcus Doherty of The Australian National University. Their results have been published in *Nature Communications*.

QUANTUM LABS, INCLUDING BASSETT'S, HAVE BEEN EXPLORING OTHER MATERIALS WITH ROOM-TEMPERATURE QUBITS BASED ON DEFECTS.

QUANTUM WORLD COMPUTING

Quantum computers promise to tackle complex problems at lightning speeds, enabling applications like rapidly simulating the physical world at the molecular level. Their promise lies in the fundamentally different way in which they represent information. Classical computers use transistors to store data and perform calculations with binary bits, electronic signals that represent 0 or 1. Quantum computing will instead rely on qubits, which use subatomic states such as the spin of an electron, to represent a 0, 1 or a superposition of both at the same time.

Classic binary bits are like a coin on a flat surface, always either heads or tails. Qubits, on the other hand, are like a flipping coin suspended in mid-air, allowing them to represent 0 and 1 simultaneously until they are measured. Along with entanglement, or the ability of physically separated states to influence one another, these properties allow quantum systems to store more information and process certain calculations much faster than classical computers.

But because measuring a qubit causes its 0-and-1 superposition to collapse, quantum systems are extremely fragile. Certain arrangements of atoms, like the defects Bassett and his colleagues discovered in h-BN, can serve as insulated, protected pockets for qubits. And because h-BN is two-dimensional, the qubits they contain are easily accessible.

2D KEY

Quantum labs, including Bassett's, have been exploring other materials with room-temperature qubits based on defects. Bassett's lab also studies defects in the crystalline lattice of diamonds, which are known to harbor spin states that act as excellent quantum memories, quantum communication links and nanoscale quantum sensors.

QUANTUM COMPUTERS PROMISE TO TACKLE COMPLEX PROBLEMS AT LIGHTNING SPEEDS, ENABLING APPLICATIONS LIKE RAPIDLY SIMULATING THE PHYSICAL WORLD AT THE MOLECULAR LEVEL.

Diamond-based technology is poised to be useful for quantum systems that need to withstand extreme conditions. But bulk materials pose other challenges; in particular, it is difficult to create and locate precise arrangements of defect qubits on the atomic scale within a 3D crystal.

The discovery of analogous defect-bound qubits in a 2D material, such as h-BN, can address this challenge. Because h-BN is only one atom thick, the qubits are always on its surface, and tools are available to directly image and control individual atoms.

Not only does this make the spins accessible to researchers, it also makes the spins accessible to other quantum states in nanoscale devices, which would help create applicable quantum technology.

Bassett and his team will take this research even further thanks to the JEOL NEOARM transmission electron microscope housed at Penn's Singh Center for Nanotechnology. The NEOARM, the only microscope of its kind in the country, can visually image single atoms, which will allow the researchers to develop a more complete understanding of h-BN defects and even create new ones.

"There are long-term, exciting goals involving this system," Basset says. "This could eventually enable all sorts of technology, because the material offers unprecedented levels of control."

QUANTUM QUAKERS

Hopper, who will be the first student to graduate with a Ph.D. from Bassett's Quantum Engineering Lab, says that while he's grateful for his advisor's surfing knowledge, he is most thankful for the environment he creates in his lab.

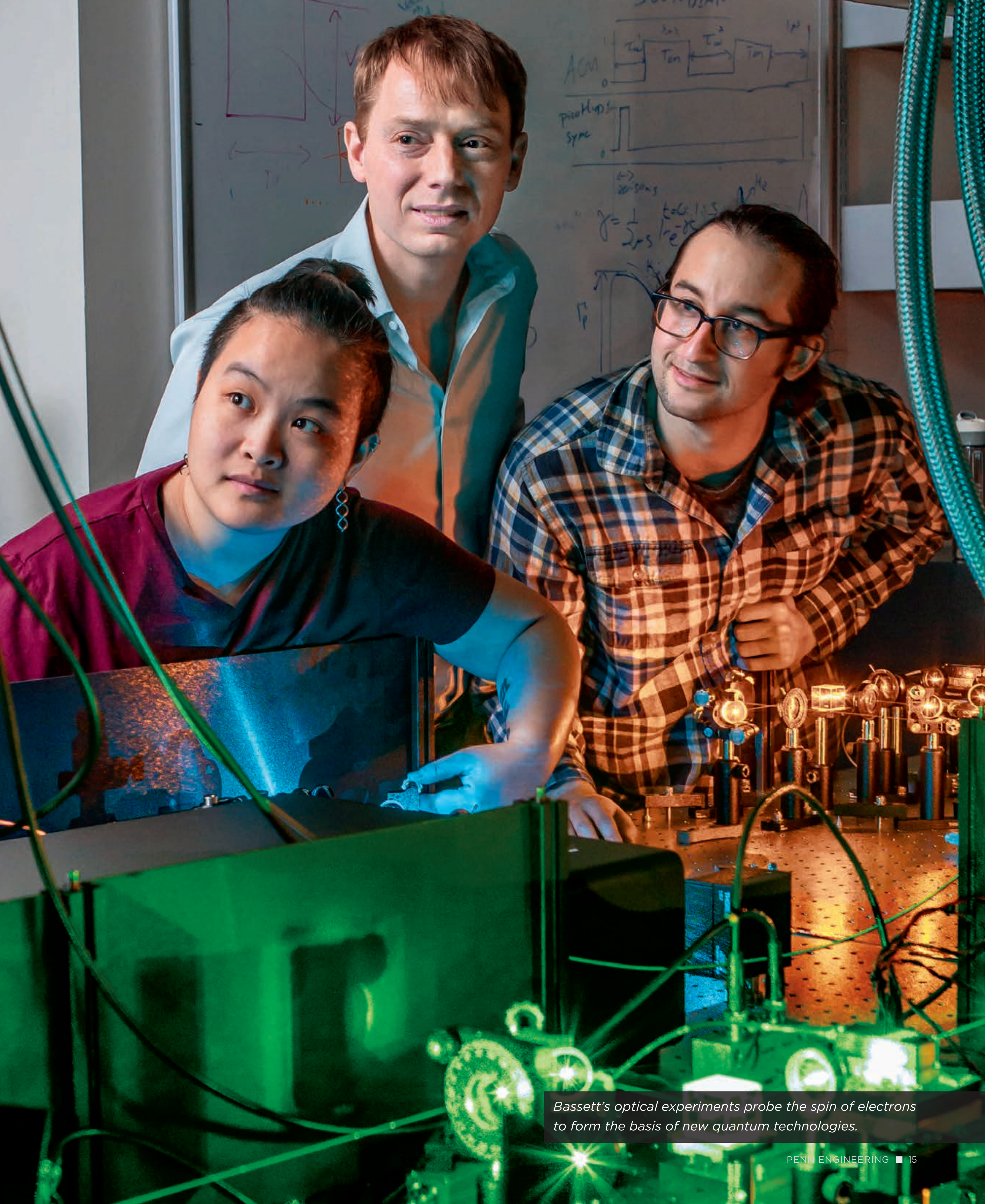
"Lee does a really great job of bringing together people who enjoy working with others," Hopper says. "He encourages us to leverage one another's strengths, which makes it really easy to build and share expertise. He's always encouraging discussions and collaborations, which makes for such a healthy environment, not only for the lab to grow, but for individuals to grow as well.

"Whether it's in the lab or in the water, Lee's one of those people who is so knowledgeable about anything that interests him."

Bassett says that he too is grateful for the students in his lab, attributing their success to the overall environment at Penn, as well as the lab's diverse background.

"There's such an intellectually rich atmosphere at Penn," Bassett says. "Our lab is a diverse mix of people who come from backgrounds in materials science, quantum physics, photonics and device engineering, but also from biomedicine, chemistry and more. This is the perfect storm for pioneering quantum research, because quantum science and technology encompasses so many disciplines, all while sort of defying a clear definition. Penn's overall environment aligns with that idea, which helps to make our lab unique and successful."

By Jacob Williamson-Rea



Bassett's optical experiments probe the spin of electrons to form the basis of new quantum technologies.

MAURA KIMMEL (CBE'20)

Quakers on Track

PENN ENGINEERING'S SCHOLAR-ATHLETES

From the vantage point of her final semester, student athlete and senior Rachel Lee Wilson is able to offer encouragement to any prospective Penn Engineering students who also aspire to participate in competitive sports: "It's hard," she said with a relieved and knowing smile, "but it's possible!"

The reputed difficulties of science, technology, engineering and mathematics (STEM) college courses in combination with the daunting demands of high-level collegiate athletics did not deter Wilson, a Chemical and Biomolecular Engineering (CBE) major and record-shattering indoor and outdoor thrower for the University's Track and Field team. Then again, it's not likely that anyone who can write the words "Quantum Physics of Materials" and "All American Hammer Thrower" on the same resume has backed down from many challenges.

WALK-ON TO ALL-AMERICAN

A two-time state finalist in discus and shot put while in high school, Wilson picked up the hammer throw as an additional event during her junior year of high school. A 4 kilogram metal ball attached to a grip by a 19.4 centimeter wire expanded Wilson's field sport repertoire. She was a triple throwing threat by the time she joined Penn's Track and Field team as a first-year walk-on.

There has been no pause in the momentum. Wilson continues to best her own throwing records, toppling the University's while she's at it. She is the first hammer thrower in Penn Women's Track and Field history to have advanced to the National Collegiate Athletic Association (NCAA) championship final round.

Seemingly born organized, Wilson has made the time to serve as president of Penn's chapter of the National Society of Black Engineers (NSBE). In fact, she attributes much of her academic and athletic success to the encouragement she has received from her NSBE peers. Her teammate, fellow CBE major and "little bud," Maura Kimmel, also figures prominently in her support network.

Kimmel, currently a junior, was recruited to Penn Track and Field by former throwing coach Tony Tenisci. Tenisci's promotional efforts are known to have greatly contributed to the establishment of the women's hammer throw as a U.S. competitive event. After 30 years of coaching track and field at Penn, he would soon retire, but not before inspiring Kimmel with his enthusiasm for her considerable abilities as a discus thrower and shot putter.

IT'S NOT LIKELY THAT ANYONE WHO CAN WRITE THE WORDS "QUANTUM PHYSICS OF MATERIALS" AND "ALL AMERICAN HAMMER THROWER" ON THE SAME RESUME HAS BACKED DOWN FROM MANY CHALLENGES.

With an aptitude for all things STEM and an irrepressible curiosity about how things work, Kimmel was a perfect fit for Penn Engineering. But while Kimmel received an acceptance letter to the School, her beloved golden retriever Pacer did not make the cut. He waits patiently with her parents in West Sunbury, PA, for the opportunity to join her.

Kimmel was still navigating the newness of a large urban campus and experiencing the excitement of high-level collegiate athletics when a vertebral stress fracture altered the trajectory of her freshman year. She quickly found herself

Penn Engineering scholar-athletes (pictured from left) Nathan Fisher (MEAM'20), Maura Kimmel (CBE'20), Rachel Lee Wilson (CBE'19) and Campbell Parker (BE'21) line the track at Franklin Field.

on another kind of team altogether: Her coaches, trainers, Engineering faculty and members of Penn's medical community joined forces to keep her thriving academically and athletically. Despite her injury, Kimmel closed out the year having broken Penn's indoor record in shot put and the outdoor record for the discus throw.

By the time she won the 2019 Ivy League Heptagonal Championship shot put with a throw of 16.07 meters, it was clear that she is pretty much unstoppable. A self-described problem solver, Kimmel has somehow figured out how to fit five courses, two to three hours of throwing practice and a customized conditioning regimen into a typical 24-hour day at Penn.

While other athletes may be introduced to their sport by a family member or in front of the TV, Nathan Fisher, a Mechanical Engineering and Applied Mechanics (MEAM) junior, came upon pole vaulting by way of a dare. As a freshman at Strake Jesuit College Prep in Houston, TX, Fisher and a friend were preparing for baseball tryouts when they agreed to formulate a Plan B should they not make the team: The two friends would take up the "weirdest" possible sport to pursue in place of baseball. When denied a place on the baseball team roster, Fisher found himself up in the air at the end of a five-meter pole.

RAISING THE BAR

Fisher was beyond excited to receive a lightning-quick response to his high school online recruiting profile from Joe Klim, Penn's assistant vertical jumps coach. Klim liked what he saw: At that point, Fisher had been inducted into Strake's chapter of the National Honor Society and was consistently raising the bar in pole vaulting competitions.

Now working with Klim daily, Fisher is impressed by his coach's flexibility and willingness to work with the stringent course scheduling required by the engineering curriculum. Very little white space remains on Fisher's calendar, and the arrangement of his practice schedule seems to be working: He brought home to campus First Team All-Ivy 2019 honors with a "Heps" win in the men's pole vault.

Fisher does not hold back when voicing a group brag. Some of his Penn Engineering track and field teammates are highly competitive at the national level and he's quite proud of their achievements. He places a high value on his teammates as friends, among them Campbell Parker.

Enjoying what could be described as a holistic education at Penn, Parker is a sophomore discus and hammer and weight thrower studying Bioengineering and, as a minor, Cinema Studies. As the first recruit of Penn's assistant throws coach, Jeff Pflaumbaum, Parker had gained accolades in the discus throw, shot put and hammer throw throughout high school, and graduated fourth in his class at Greencastle-Antrim in Greencastle, PA.

Finishing up what he has been told would be his "easiest" semester, Parker was shouldering a course load of five and a half credits. He was quick to insert an imaginary exclamation point behind the "half" credit, giving "massive props" to Michael Stevens, instructor of Music 007, and director of the Brazilian Samba Ensemble.

Underlying his joy of drumming with the ensemble every week is Parker's awareness of the high stress level that pervades extremely competitive campuses like Penn and his need to let off steam. Parker says that self-acceptance and the appreciation of his own unique strengths and talents are the keys to his success. However ironically, he appears to have set "Not Taking Myself Too Seriously" as a personal goal.

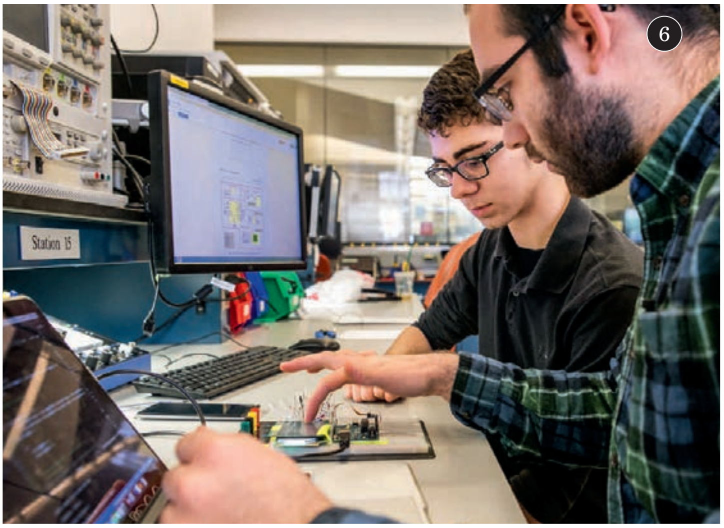
KIDS, MEET "CAVEMAN"

One effective strategy for "keeping it real" is to get out and help others, and Parker will join Nate Fisher as a counselor representing Penn at Camp Kesem this summer. Kesem is a national volunteer effort by college students to support and provide guidance to children whose parents are dealing with cancer. Having adopted the nickname "Caveman" as his fundraising moniker for the camp, Penn's bearded bioengineer, hammer thrower and aspiring screenwriter is sure to inspire a little awe and a lot of admiration from the Kesem campers.

By Patricia Hutchings

On Our Camera Roll

1. Penn Engineers gather on Smith Walk before class. **2.** Bryan Chem, Mathew Halm and David Levine, doctoral students in MEAM, convert handwritten equations into simulation software. **3.** Konrad Kording speaks with a student during the "Growing Up in Science" event, where science professionals share stories about the successes and failures in their careers. **4.** For Senior Design, Team Glacion students are developing a refrigeration-cycled cooling vest for workers who suffer from heat stroke in high temperatures. **5.** Rosalind Shinkle, a master's student in the Kod*Lab, creates a simulation of a robot navigating among moving obstacles.



6. Undergraduates enrolled in ESE 350 learn to use touch screens for controlling actuators in the Detkin Lab. **7.** Alexis Mitchnick screws a motor mount to a voice-controlled third arm for Dextera, a Senior Design project. **8.** The Singh Center for Nanotechnology offers a serene space for study, lunch and relaxation. **9.** C.J. Taylor and students enjoy some fun during a meeting for Penn's DARPA Subterranean (SubT) Challenge. **10.** CBE undergraduates observe the separation of green fluorescent protein from bacteria.

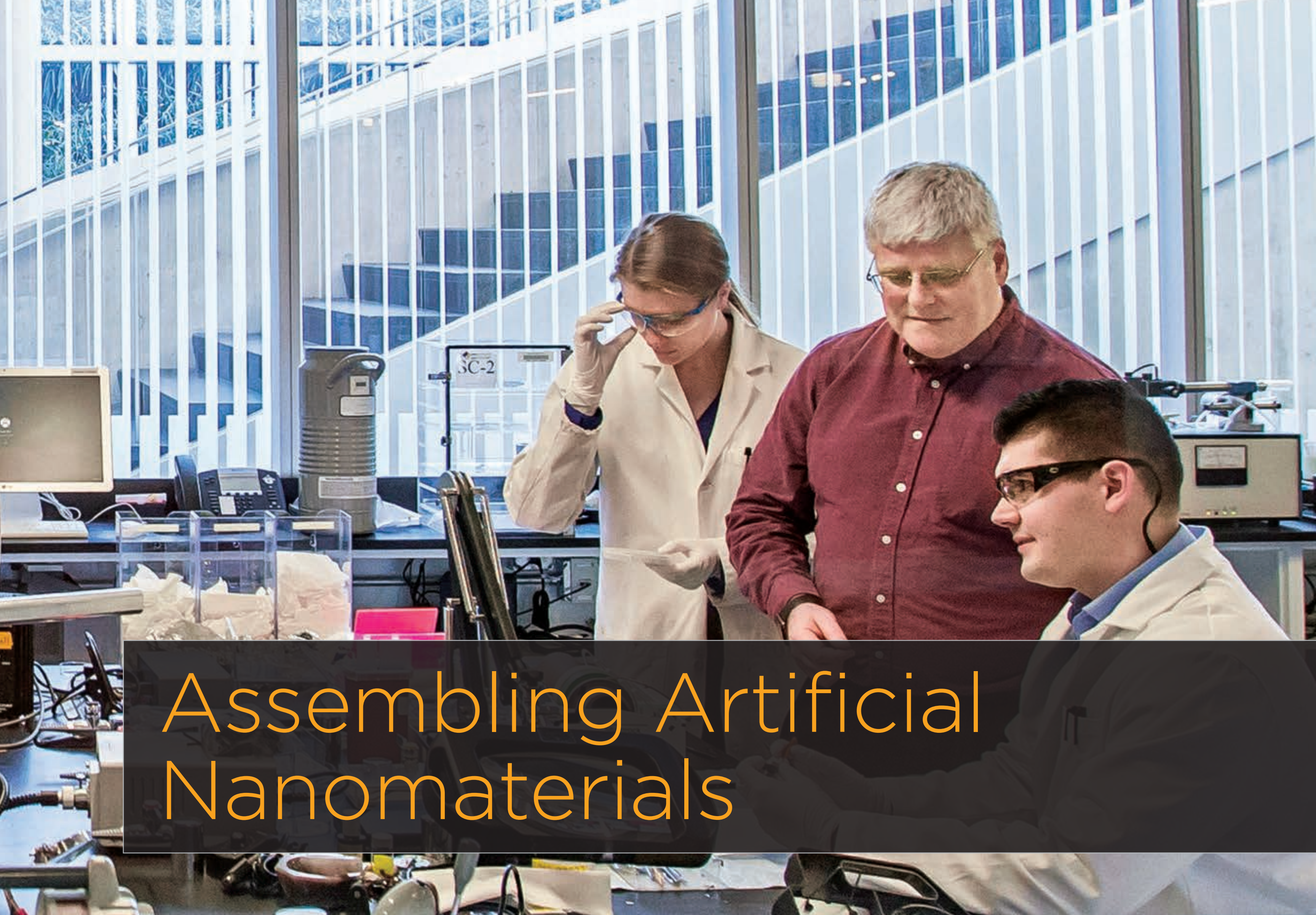
Many materials, whether natural or synthetic, have only one or two physical functions or properties. Whether a material ends up being metallic, magnetic or insulating depends on the type, number and arrangement of atomic building blocks. Unfortunately, chemical bonding constraints that prevent the coexistence of multiple properties have limited the quest to synthesize advanced materials.

"WE ARE WORKING TO IDENTIFY THE DESIGN RULES AND THE FUNDAMENTAL PROCESSES AND PHYSICAL PHENOMENA THAT CONTROL THE ASSEMBLY AND EMERGENCE OF NEW PROPERTIES."

But this paradigm is about to shift, thanks to the hard work of researchers at Penn Engineering, the University of Michigan and the Massachusetts Institute of Technology (MIT). The team of world-renowned experts, spanning the fields of chemistry, physics and engineering, has set its sights on developing a blueprint for the design and assembly of multifunctional, adaptive materials that combine three or more independent physical properties. To accomplish this feat, they will replace the traditional periodic table with a library of inorganic colloidal nanocrystals serving as artificial atoms.

"In this program, we are working to identify the design rules and the fundamental processes and physical phenomena that control the assembly and emergence of new properties," says Christopher Murray, Richard Perry University Professor in Materials Science and Engineering and in Chemistry at Penn. "If we're successful, we can share with the rest of the world this set of procedures, with which you can define the blueprints to build other systems."

The project will be managed by Murray and Cherie Kagan, Stephen J. Angello Professor in Electrical and Systems Engineering at Penn. The husband-and-wife



Assembling Artificial Nanomaterials

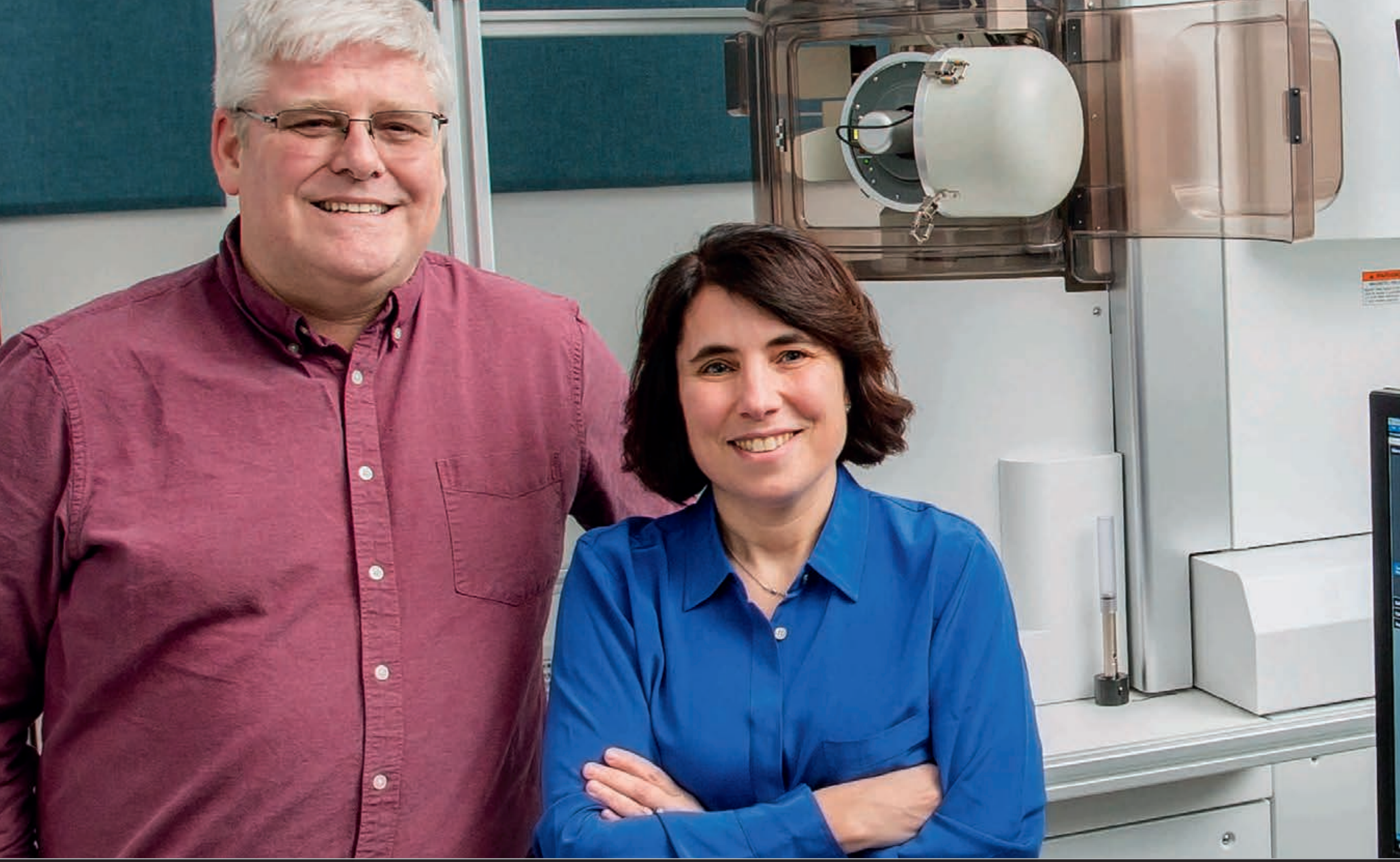
duo will be joined by three additional co-principle investigators: Sharon Glotzer, Anthony C. Lembke Department Chair, and Nicholas Kotov, Joseph B. and Florence V. Cejka Professor, both in the Chemical Engineering department at the University of Michigan; as well as Ju Li, the Battelle Energy Alliance Professor of Nuclear Science and Engineering at MIT. The endeavor will be supported by a five-year, $7.5 million Multidisciplinary University Research Initiatives (MURI) grant from the Office of Naval Research at the U.S. Department of Defense.

"The team really represents the absolute best in all the different sub-disciplines that bring together the whole project," Kagan says. "We're thrilled about the scientific goals and the opportunity for basic science, but the MURI program is an opportunity to bring together the very best people cutting across institutions and areas of expertise. To have the freedom to form that kind of a dream team around a specific topic is one of the best experiences as an academic researcher."

BUILDING THE BLUEPRINT

To engineer the multifunctional materials, the researchers will combine new techniques in atomistic modeling and chemical simulations to design blueprints that will guide the synthesis and assembly of a library of nanocrystals. They will assemble architectures at multiple spatial scales and exploit the nanocrystals' physical properties, which vary depending on their size, shape and composition. Multiple properties can be integrated in a super-particle by matching the sizes and shapes of the nanocrystals.

A large part of this project is the concept of self-assembly. "One builds the components, but also tailors the chemistry and conditions, so that those LEGO blocks will actually know how to fit themselves together to build the larger structures," Murray explains. "The major advantage is you don't have to go in and design where everything is going to fit. If you get the rules right, then the system will assemble itself with an interesting and functional architecture



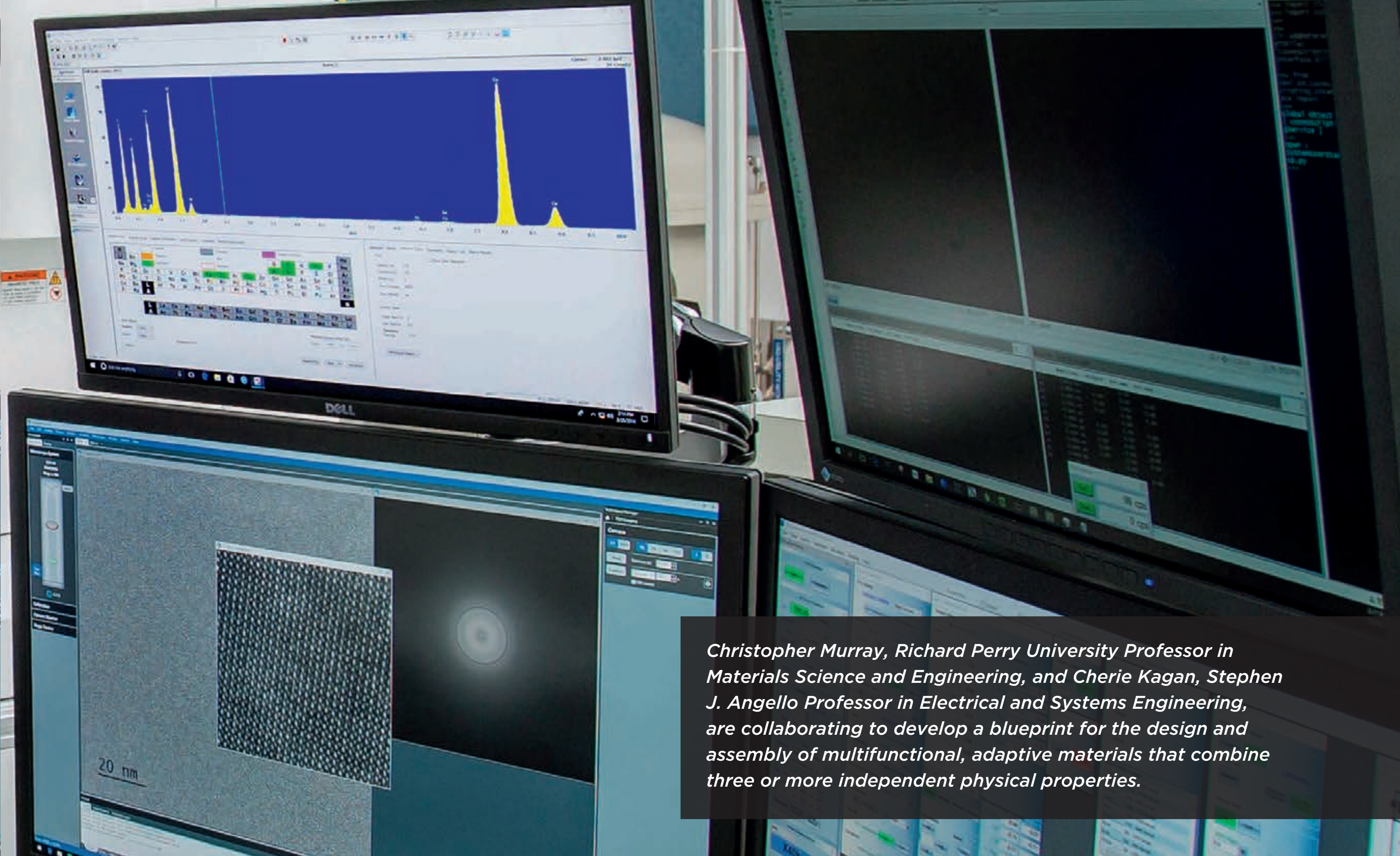
based on the chemical and physical principles that we've outlined."

The self-adaptive material superstructures that are constructed will reversibly or irreversibly modify their electromagnetic, mechanical, chemical, thermal or electrical properties in response to external stimuli, such as changes in temperature, mechanical stress, electrochemical voltage or electromagnetic waves. For example, directional stress could trigger an insulator-to-metal transition in an assembly of nanocrystals. Meanwhile, another material could switch from light-absorbing to highly reflective in response to changes in temperature or exposure to radiofrequency or microwave irradiation.

"There is some change in the operating environment, and the system can protect or optimize itself by shutting down or changing how the subcomponents of the material are coupled," Kagan explains. "We do this in technology today by integrating many different circuits in devices and building things out at the scale of the system architecture. But what we are working on in this project is to try to take many of those functions that are fabricated on the micron scale and actually capture those from the atomic scale upward, basically to get materials to do the smart sorts of things that fabricated computer systems and circuits might do."

THIS WORK WILL PROVIDE A GENERAL BLUEPRINT FOR MATERIALS DESIGN APPLICABLE TO BIOSENSORS, ELECTRONICS, ENERGY-CONVERSION DEVICES, PHOTONICS AND EVEN PHARMACEUTICALS.

But it's not a trivial task to bring the building blocks together. "It's not a simple coexistence. The presence of one influences and can steer the response of the other," Murray says. "It's a grand challenge to be able to simultaneously control many different parts or components and to learn the rules that allow you to implement self-assembly strategies. We need to understand the building blocks, their response in their own right, as well as



Christopher Murray, Richard Perry University Professor in Materials Science and Engineering, and Cherie Kagan, Stephen J. Angello Professor in Electrical and Systems Engineering, are collaborating to develop a blueprint for the design and assembly of multifunctional, adaptive materials that combine three or more independent physical properties.

the way they interact with one another, and the interactions can be very nonlinear and complicated."

LAYING THE FOUNDATION

Although this project focuses on basic science, it could pave the way for a wide variety of civilian and military applications. This work will provide a general blueprint for materials design that could be applicable to biosensors, electronics, energy-conversion devices, photonics and even pharmaceuticals. From a military perspective, the nanocrystal structures could eventually enhance battlefield awareness; lead to the development of high-performance, lightweight materials essential for combat soldiers; or open the possibility of hidden communication bandwidths impervious to enemy interference. Moreover, adaptive magnetic materials could one day protect against electromagnetic interference ranging from solar flares to electromagnetic pulse weapons.

"It's really about fundamental materials discovery and materials engineering in this project," Kagan says. "If you have the good basic science, then you can take that in many different application directions. If the science is not good, then you don't have anywhere to go. The key is to make sure we're on solid ground and build properly from the bottom up."

The solid ground to support this ambitious endeavor is provided by Penn's stellar students and cutting-edge resources and facilities, such as the Singh Center for Nanotechnology, which Murray and Kagan will leverage to fabricate and characterize the nanocrystal-based materials.

"There are strengths at Penn that allow us to build these kinds of multidisciplinary and multi-institutional partnerships that really are only possible because of a lot of hard work and a lot of smart people who make up Penn's ecosystem," Murray says. "This kind of work is only possible because of some very big, decades-long investments that the University has made, and a vision to advance in the areas of characterization and fabrication. But this is an example of just one of the types of research initiatives that now have been nurtured by access to those capabilities. And we think it's just the tip of the iceberg."

By Janelle Weaver

Coding with Kids

NURTURING MIDDLE SCHOOLERS' INTEREST IN COMPUTER SCIENCE

When Desiree Penaranda (CIS'20) asked the wide-eyed 11-year-old girls gathered around her why they wanted to be in the Girls Who Code after-school club, she was astounded by their answers.

"They all said they wanted to be hackers," says Penaranda. Surprised by their responses, Penaranda and her co-leader Deniz Kecik (CIS'20) made a quick pivot. They showed the girls the computer coding projects they were working on as undergraduates at Penn Engineering.

"Deniz and I learned that the girls were as interested in computer games as we were, so we focused on that. In 12 weeks, the girls designed and coded their own race car game," explains Penaranda. "From there, we moved on to showing them how to develop their own web pages. They learned they have what it takes to master coding and better understand the utility of computers. I was so proud of them."

INSPIRING STUDENTS TO CODE

More than 30 Penn Engineering computer science students have taught 135 middle school students in the Philadelphia area in multiple after-school coding clubs since 2017, under the auspices of the Fife-Penn CS Academy. The Penn Engineering club leaders are helping to break down barriers in education and inspire young students to consider computer science careers.

"Our goal is two-fold," explains Rita Powell, director of Diversity and Belonging in the Department of Computer and Information Science and co-founder of the Academy. "We want to nurture middle school students' interest in computer science and their tenacity as problem solvers. By placing Penn students in the classroom as club leaders, we are also helping to increase their confidence."

The Academy, funded by the Lori and Mark Fife Foundation, is geared to enhance students'

Coding club instructors Ryan Martinez, Alara Gebes and Alexandra Rumyantseva prepare lesson plans.

education and prepare them for the 21st century economy. “Learning a skill like coding can help to increase the professional opportunities that young scholars in our Philadelphia schools have and will help them become better problem solvers,” says Mark Fife (W’78), Academy co-founder. “By providing this opportunity, we hope to create the next generation of entrepreneurs and creative thinkers.”

CHANGING PERCEPTIONS

The Academy runs 10 separate Girls Who Code and Boys Who Code clubs in five local middle schools: Penn Alexander School, Henry C. Lea Elementary, KIPP West Philadelphia Preparatory Charter School, James Rhoads School and Bala Cynwyd Middle School. Two Penn Engineering computer science students teach between 5 and 19 boys or girls in each club.

Because a majority of the student club leaders are women like Penaranda, it does not come as a surprise that they are most proud of teaching other girls to learn to believe in themselves and undertake a task that has typically been dominated by men. “I have been able to motivate and encourage girls about computer science just as I was encouraged back in high school,” explains Penaranda. “Without that encouragement, I would not be preparing for a career I love.”

PENN ENGINEERING CLUB LEADERS ARE HELPING TO BREAK DOWN BARRIERS IN EDUCATION AND INSPIRE YOUNG STUDENTS TO CONSIDER COMPUTER SCIENCE CAREERS.

But helping younger students learn to code is also a way for Penn Engineering computer science majors to give back to the Philadelphia community and

help change some preconceptions about coding and computer science. "There's an idea that you have to be 'techy' to pursue fields such as computer science and this can be discouraging for people who are not naturally like that," says Alara Gebes (ECON'20; CIS'20), who has led both Girls Who Code and Boys Who Code clubs. "I think it's crucial to show kids that it's all about the passion for learning, having an inquisitive mind and challenging yourself. I want my students to learn that no matter what field they go into, they shouldn't let such norms stop them from trying something that really interests them."

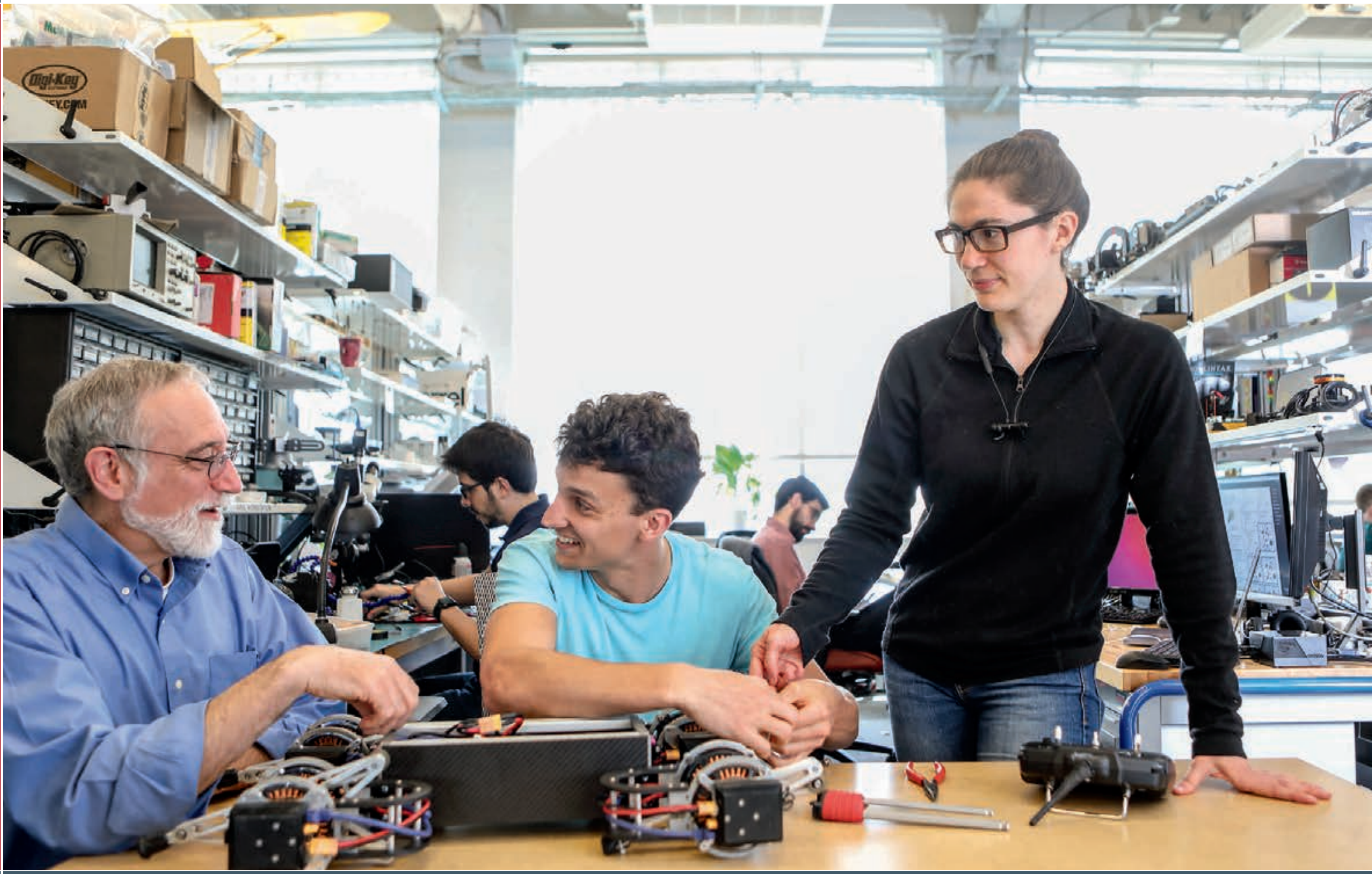
LESSONS LEARNED

Fife and Powell are encouraged by the interest in the clubs, both from the middle schoolers and the Penn Engineering students. In the coming years, they hope to have clubs running in 20 schools. "We want to give as many young people as possible the opportunity to learn, create and succeed at whatever career they decide to pursue," says Fife.

The clubs also impact the Penn Engineering student leaders. Many say they learn so much more about themselves when they make the commitment to share their love for computer science. "The boys in my club are always teeming with excitement," says Ryan Martinez (CIS'22), who teaches a Boys Who Code club at Lea Elementary School. "It astounds me that in lieu of playing basketball or other sports after school, they choose to come to coding club. Something like that requires hard work and can seem like school."

By helping his students learn to code and persist to solve tougher coding problems, Martinez has learned some valuable lessons about himself. "Taking on this responsibility requires a tremendous amount of patience, and I've learned I need to improve mine," he says. "But more importantly, I've learned that what I teach the kids applies to me too. To push through on a tough problem, I need to be okay about not getting the right answer right away and to find a way to keep working without getting frustrated."

By Amy Biemiller



Sebastian Angel

Raj and Neera Singh Term Assistant Professor
Computer and Information Science

Ph.D. in Computer Science;
University of Texas at Austin

Anindya De

Assistant Professor
Computer and Information Science

Ph.D. in Computer Science;
University of California, Berkeley

Marc Miskin

Assistant Professor
Electrical and Systems Engineering

Ph.D. in Physics;
University of Chicago

Troy Olsson

Assistant Professor
Electrical and Systems Engineering

Ph.D. in Electrical Engineering;
University of Michigan

UNIVERSITY OF PENNSYLVANIA 2019 TEACHING AWARDS

Andreas Haeberlen, *Associate Professor in Computer and Information Science,* is the recipient of a Lindback Award for Distinguished Teaching, the University's highest teaching honor.

Chris Murphy, *Associate Professor of Practice in Computer and Information Science,* is the recipient of a Provost's Award for Teaching Excellence by Non-standing Faculty.

PENN ENGINEERING 2019 TEACHING AWARDS

Igor Bargatin, *Class of 1965 Term Assistant Professor in Mechanical Engineering and Applied Mechanics,* has been awarded the S. Reid Warren, Jr., Award, which is presented annually by the undergraduate student body and the Engineering Alumni Society in recognition of outstanding service in stimulating and guiding the intellectual and professional development of undergraduate students.

David F. Meaney, *Solomon R. Pollack Professor and Chair of Bioengineering,* has been awarded the Ford Motor Company Award for Faculty Advising. This award recognizes dedication to helping students realize their educational, career and personal goals.

Swapneel Sheth, *Senior Lecturer in Computer and Information Science,* has been awarded the Hatfield Award for Excellence in Teaching in the Lecturer and Practice Professor Track. This award recognizes outstanding teaching ability, dedication to innovative undergraduate instruction, and exemplary service to the School in consistently inspiring students in the engineering and scientific profession.

GREAT FACULTY

HONORS & AWARDS

Firooz Aflatouni, *Skirkanich Assistant Professor in Electrical and Systems Engineering,* has been awarded an Office of Naval Research 2019 Young Investigator Program Award for his proposal "Deep Networks with Ultra-Fast Photonic Training for Instantaneous Direct Image Classification."

John Crocker, *Professor in Chemical and Biomolecular Engineering,* has been named a Fellow of the American Physical Society for "contributions to the microrheology of soft matter and cells, and to DNA-directed colloidal self-assembly."

André DeHon, *Professor in Electrical and Systems Engineering,* has been named to the 2018 Association for Computing Machinery (ACM) Fellowship class for "contributions to architecture exploration and design automation of spatially programmable computing fabrics, especially FPGAs [field programmable gate arrays]."

Liang Feng, *Assistant Professor in Materials Science and Engineering,* has been selected to receive a 2019 NSF CAREER Award. This award is the NSF's most prestigious award in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research within the context of the mission of their organizations.

Deep Jariwala, *Assistant Professor in Electrical and Systems Engineering,* has been awarded funding through the Army Research Office's Young Investigator Program (YIP). YIP awards are one of the most prestigious honors bestowed by the Army on outstanding scientists beginning their independent careers.

Sanjeev Khanna, *Henry Salvatori Professor in Computer and Information Science,* has been named to the 2018 Association for Computing Machinery (ACM) Fellowship class for "contributions to approximation algorithms, hardness of approximation, and sublinear algorithms."


Firooz Aflatouni


John Crocker


André DeHon


Liang Feng


Deep Jariwala


Sanjeev Khanna


Michael Mitchell


Christopher Murray


James Pikul


Vivek Shenoy


Cynthia Sung


Mark Yim

Michael Mitchell, *Skirkanich Assistant Professor of Innovation in Bioengineering,* has received a Rising Star Award in Cellular and Molecular Bioengineering from the Biomedical Engineering Society's Cellular and Molecular Bioengineering Special Interest Group.

Christopher Murray, *Richard Perry University Professor and Professor in Materials Science and Engineering,* has been elected to the National Academy of Engineering (NAE) "for invention and development of solvothermal synthesis of monodisperse nanocrystal quantum dots for displays, photovoltaics and memory."

James Pikul, *Assistant Professor in Mechanical Engineering and Applied Mechanics,* has been awarded an Office of Naval Research 2019 Young Investigator Program Award for his proposal "Understanding Electrochemically Induced Surface Evolution and Transport at Metal-Hydrogel Interfaces for Metal-Air Scavenger Power."

Vivek Shenoy, *Eduardo D. Glandt President's Distinguished Professor in Materials Science and Engineering,* has been named the recipient of the 2018-19 George H. Heilmeier Faculty Award for Excellence in Research for "pioneering multi-scale models of nanomaterials and biological systems."

Cynthia Sung, *Gabel Family Term Assistant Professor in Mechanical Engineering and Applied Mechanics*, has been selected to receive a 2019 NSF CAREER Award. This award is the NSF's most prestigious award in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research within the context of the mission of their organizations.

Mark Yim, *Professor in Mechanical Engineering and Applied Mechanics,* has been named a 2018 National Academy of Inventors fellow for "demonstrating a highly prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on the quality of life, economic development, and welfare of society."

Suzanne Rowland

INSPIRING PROFITABLE TEAMS

"My training as an engineer is at the heart of how I think, work, lead teams and solve problems," says Suzanne Rowland (ChE'83), who grew up in a Pennsylvania town of 5,000 and was the first person in her family to attend college. Her horizons were forever broadened during her undergraduate years and her Penn-supported fellowship for a master's degree from the London Business School.

Rowland, who retired in March from leading a $1.2 billion division of Ashland Global Holdings, Inc. (NYSE: ASH), shares her expertise in strategy development, execution and team engagement as an advisor and consultant to companies undergoing significant change. She serves on Penn Engineering's Board of Overseers as well as on corporate boards, and looks forward to working and traveling globally in this next chapter of her illustrious career.

What types of challenges interest you?
I'm most excited by opportunities to improve businesses through growth or a turnaround, especially when there's a chance to energize a team to achieve a bigger goal than anyone thought possible.

Who at Penn influenced you most?
As I reflect now, three professors through their courses and their caring changed my trajectory. Raymond Gorte's process control course influenced how I develop repeatable processes in all aspects of business. The thermodynamics course with Eduardo Glandt inspired me as well, because as he says, thermodynamics explains life, which is about entropy and making order out of chaos (or trying to, anyway). The late John Quinn encouraged me to apply for Penn's Thouron Award, which fully funded my master's degree in London, a pivotal experience for me.

What advice would you offer to engineering students?
Engineering can be quite challenging. My advice is to stay with it and know that the intensity will be well worth it in the end. Take advantage of all that Penn has to offer beyond Penn Engineering and look for opportunities to build a network with people who will be important throughout your life.

How has Penn Engineering changed?
Since I joined the Board over 15 years ago, the world's need for engineering's integrated approach and interconnectivity with other disciplines has grown exponentially. Penn has adapted tremendously to this with the extensive interplay and collaboration between its preeminent schools. Dean Eduardo Glandt led an era of building infrastructure. Dean Vijay Kumar is taking that forward and expanding the School with new faculty, new courses and more engineering students, which is fantastic.

By Jessica Stein Diamond

Penn Engineering Board of Overseers

Penn Engineering
School of Engineering and Applied Science
University of Pennsylvania

123 Towne Building | 220 South 33rd Street
Philadelphia, PA 19104-6391

Non Profit Org.
U.S. Postage
PAID
Permit No. 2563
Philadelphia, PA

LIL BUB

In 2015, Orsolya Symmons, now a postdoc in the lab of Bioengineering professor Arjun Raj, began a project designed to answer a question on the minds of millions of people on the internet: Why does this cat look like that?

"Lil Bub" gained worldwide social media fame for her unusual, and unusually cute, appearance. Sporting extra toes, stubby legs, no teeth and a shortened jaw that leaves her tongue perpetually poking out, Lil Bub's genes were sure to contain some clues.

Symmons, along with her collaborators and Mike Bridavsky, Lil Bub's owner, set up a historic crowdfunding effort that would allow them to sequence the cat's genome. This fall, the team published the results of the "LilBUBome," showing two key mutations: one responsible for Lil Bub's extra toes, and another that resulted in unusually dense bones, which stunted her growth. By discussing their research in a clear and public way, Symmons and her colleagues were able to share the joy of Lil Bub and teach the world a bit about genetics in the process.